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**SECOND FORMAL PROGRAM REVIEW BRIEFING FOR  
MARSHALL SPACE FLIGHT CENTER**

**MISSION ROLES FOR THE SOLAR ELECTRIC  
PROPULSION STAGE WITH THE SPACE  
TRANSPORTATION SYSTEM**

(NASA-CR-120664) MISSION ROLES FOR THE  
SOLAR ELECTRIC PROPULSION STAGE WITH THE  
SPACE TRANSPORTATION SYSTEM (Northrop  
Services, Inc., Huntsville, Ala.) 63 p HC  
\$4.25

N75-29170

Unclas  
CSCL 21C G3/20 31058

**DECEMBER 3, 1974**



**NORTHROP SERVICES, INC.  
CONTRACT NO. NAS8-30742**

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## **MISSION ROLES FOR SEPS WITH THE SPACE TRANSPORTATION SYSTEM**

### **PRESENTATION TOPICS**

- o EXECUTIVE SUMMARY**
- o SELECTED OPERATIONAL CONSIDERATIONS AND MISSION CHARACTERISTICS**
- o TRADE STUDIES & TECHNOLOGY ASSESSMENTS INFLUENCING SEPS CONFIGURATION  
DEFINITION**
- o PROGRAM SUPPORT REQUIREMENTS**
- o DEVELOPMENT & OPERATIONS COST ESTIMATES**

## **MISSION ROLES FOR SEPS WITH THE SPACE TRANSPORTATION SYSTEM**

### **PRIMARY OBJECTIVES**

- **DEFINE ROLES CONTRIBUTING TO TRANSPORT COST EFFECTIVENESS**
- **PERFORM OPERATIONAL ANALYSES ON PAYLOAD TRANSFER & SERVICING FUNCTIONS**
- **DEVELOP CONCEPTUAL DESIGNS FOR PAYLOAD TRANSFER & SERVICING**
- **DEFINE SEPS INTERFACES WITH STS**
- **ASSESS DESIGN IMPACTS ON SEPS SUBSYSTEMS**

### **STUDY SCOPE**

**6,500 MANHOURS**

## **MISSION ROLES FOR SEPS WITH THE SPACE TRANSPORTATION SYSTEM**

### **CONTRIBUTING SECONDARY OBJECTIVES**

- **QUANTIFY TRANSPORT COST EFFECTIVENESS OF SEPS RELATIVE TO A NASA MISSION MODEL**
- **DEFINE SYSTEM OPERATIONAL PROFILE WITH FLIGHT ASSIGNMENT AND DATES. IDENTIFY NEW ROLES.**
- **IDENTIFY OPERATIONAL REQUIREMENTS AND DEFINE SEPS PROGRAM SUPPORT REQUIREMENTS**
- **ESTABLISH SEPS TRANSPORT PERFORMANCE CAPABILITIES AND SHOW POTENTIAL IMPROVEMENT**
- **IDENTIFY BENEFITS TO IUS-TUG & PAYLOADS RESULTING FROM SEPS USE**
- **IDENTIFY PROBLEM AREAS FOR FUTURE INVESTIGATION**
- **DEVELOP OPERATIONAL COSTS OF SEPS**

**SEPS FUNCTIONS IN ACCOMPLISHING THE REFERENCE MISSION MODEL\***  
**FROM 1981 TO 1991**

- o **SEPS - TUG GEOSYNCH & INTERMEDIATE ORBIT COMBINED MISSIONS COMPRISE 179 PAYLOADS ACCOMPLISHING 93% OF ALL GEOSYNCH MISSIONS, 39% OF INTERMEDIATE ORBIT MISSIONS**
- o **TUG ALONE ACCOMPLISHES 7% OF GEOSYNCH MISSIONS, AND 61% OF INTERMEDIATE ORBIT MISSIONS**
- o **4 OF 16 PLANETARY MISSIONS USE SEPS (8 LAUNCHES)**
- o **LOW EARTH ORBIT SEPS MISSIONS ARE FEASIBLE BUT NO SPECIAL COST SAVINGS WERE IDENTIFIED**

**\*REFERENCE MISSION MODEL TAKEN FROM NASA TMX-64751, REV 2  
JANUARY 1974 "THE OCTOBER 1973 SPACE SHUTTLE TRAFFIC MODEL"**



**OPERATING CONSTRAINTS INFLUENCE ON STS FLIGHTS  
REQUIRED TO ACCOMPLISH MISSION MODEL**

- GENERAL PURPOSE MISSION EQUIPMENT DESIGNS EVOLVED IN THIS STUDY MAKE ANY NUMBER OF PAYLOADS PER SORTIE FEASIBLE
- SEPS HIGH PERFORMANCE ESSENTIALLY REMOVES PAYLOAD WEIGHT PER SORTIE LIMITS
- AVAILABLE PAYLOAD VOLUME IN ORBITER CARGO BAY BECOMES THE SIGNIFICANT LIMITING FACTOR

**COMPARISON OF STS FLIGHTS REQUIRED FOR  
MISSION MODEL VS ALLOWED PACKAGING SYSTEM**

STS VARIANT/PACKAGING SYSTEM	TANDEM	SIDE BY SIDE	THREE DIMENSIONAL
BASLINE STS	497	488	488
STS WITH SEPS	489	467	461
STS FLIGHTS SAVED	8	21	27

**NUMBER OF PAYLOADS FOR TUG OPERATING ALONE LIMITED TO THREE UP AND ONE DOWN ON EACH SORTIE.**

# STS CONFIGURATION TRADES

## SHUTTLE FLIGHTS REQUIRED FOR MISSION MODEL

SEPS	TUG	30' BL TUG	30' TUG (ΔRL-10)	25' TUG	21' & 25' TUGS	REUSABLE TRANSTAGE
NO SEPS		468	480*	468	-	-
BL SEPS 10 KHR THRUSTERS		458	459*	-	465	-
BL SEPS 20 KHR THRUSTERS		458	-	455	464	-
50 KW SEPS SPSA 20 KHR THRUSTERS		456	-	454	456	-
50 KW SEPS Isp=4160 SPSA 20 KHR THRUSTERS		455	-	454	458	-
100 KW SEPS SPSA 20 KHR THRUSTERS		-	-	-	-	477**

o 90 DAY TRIP TIME LIMIT FOR SEPS

o ELLIPTICAL CHANGEOR ORBITS, PERIGEE ALT. NOT CONSTRAINED

o RADIATION EFFECTS INCLUDED

o SEPS CONFIGS. WITH 20 KHR THRUSTERS REFUELED 3 TIMES

o INTERMEDIATE ORBIT PAYLOADS NOT DELIVERED ON SEPS FLIGHTS

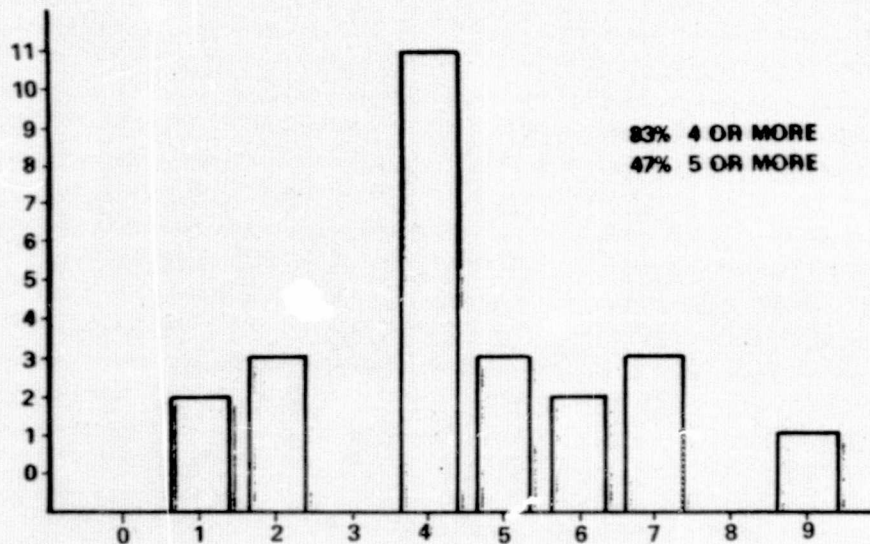
\* PLD PL-23 JUP-SAT ORBITER-LANDER COULDN'T BE DELIVERED

\*\* REQUIRES TANDEM TRANSTAGES + KICKSTAGE FOR SOME PLANETARY PLDS

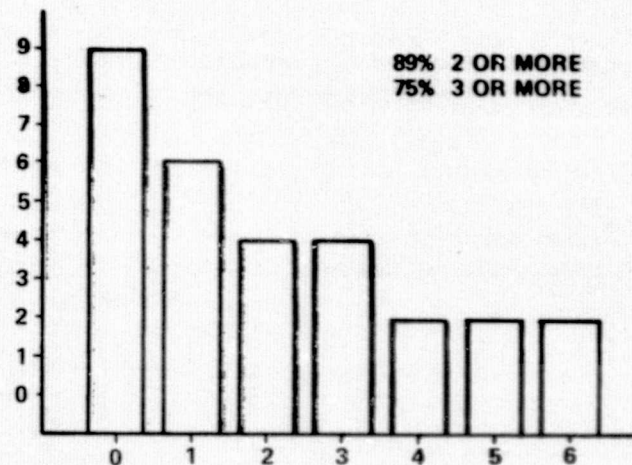
# STS OPERATIONAL TRADES

30' BL TUG WITH BL SEPS (20 KHR THRUSTERS)

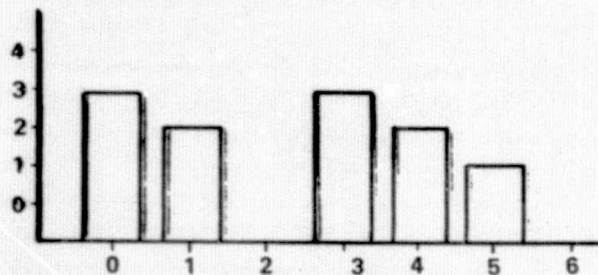
REFUELED	INTER-ORBS	CHANGE-OVER ORBITS	TRIP TIME LIMIT-DAYS	1ST SEPS LAUNCHED	RTS IN '81 THRU '83	SHUTTLE FLIGHTS REQD
3X	YES	ELLIPTICAL $r_p \geq 20000$ km RAD. IGNORED	90	1981	NO	451
3X	YES	ELLIPTICAL UNCONSTRAINED W/RAD.	90	1981	NO	452
3X	NO	ELLIPTICAL UNCONSTRAINED W/RAD.	180	1981	NO	456
3X	NO	ELLIPTICAL $r_p \geq 20000$ km RAD. IGNORED	90	1981	NO	457
3X	NO	ELLIPTICAL UNCONSTRAINED W/RAD.	90	1981	NO	458
3X	NO	CIRCULAR $r \geq 20000$ km RAD. IGNORED	90	1981	NO	460
4X	NO	ELLIPTICAL UNCONSTRAINED W/RAD.	90	1981	NO	457
3X	NO	ELLIPTICAL UNCONSTRAINED W/RAD.	90	1984	NO	457
3X	NO	ELLIPTICAL UNCONSTRAINED W/RAD.	90	1981	YES	472



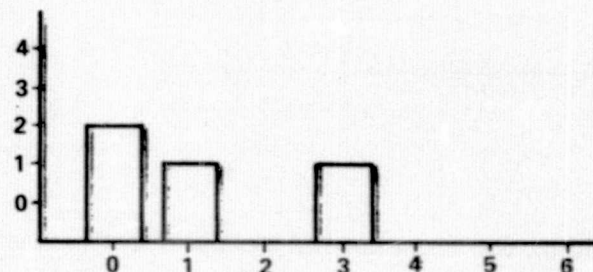
HISTOGRAM - NUMBERS OF PAYLOADS SHUTTLE IN UP MANIFESTS



HISTOGRAM - NUMBERS OF PAYLOADS IN SHUTTLE DOWN MANIFESTS



HISTOGRAM - SHUTTLE DOWN PAYLOADS IN COMBINATION WITH FOUR UP



HISTOGRAM - DOWN PAYLOADS IN COMBINATION WITH FIVE UP



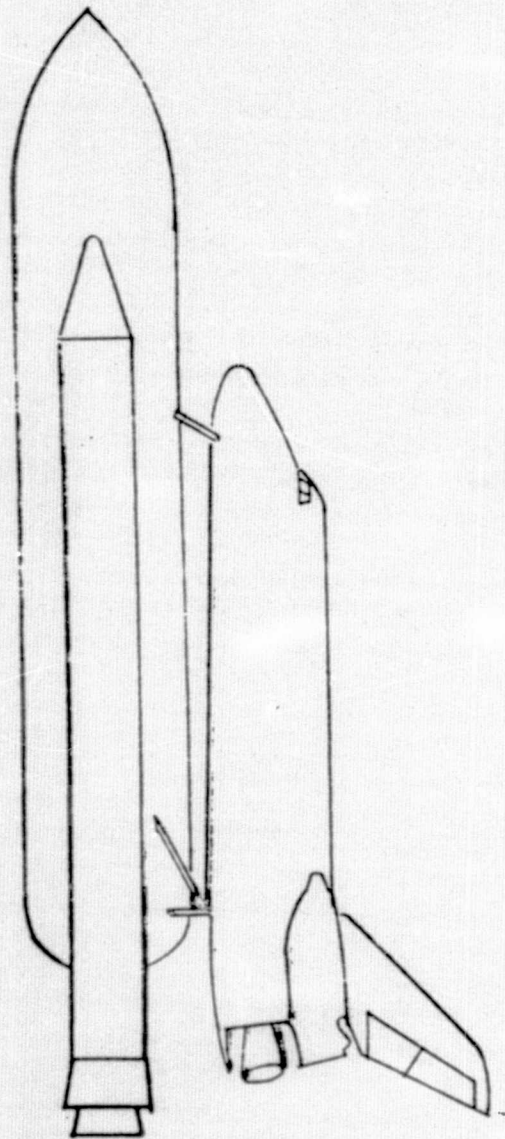
HISTOGRAM - DOWN PAYLOADS IN COMBINATION WITH SIX UP



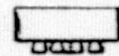
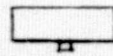
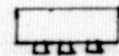
DECISION CONTROLLING FACTORS FOR  
SEPS CONFIGURATION

- TRANSPORTATION EFFICIENCY DEPENDS ON MULTIPLE PAYLOAD DELIVERIES AND RETRIEVAL
- COST EFFECTIVENESS REQUIRES GPME WITH FEW SPECIAL ITEMS
- GPME MUST SIMPLIFY SHUTTLE-TUG OPERATIONS
- MULTIPLE PAYLOAD TRANSPORT & SERVICING MUST PLACE MINIMUM CONSTRAINTS ON PAYLOAD DESIGNERS
- SEPS SPACE STAY TIME LIMITED ONLY BY WEAR OUT - EXPENDABLES ARE EASILY REPLENISHED
- GPME WEIGHT INCREASE TO SIMPLIFY OPERATIONS RESULTS ONLY IN MODEST TRIP TIME INCREASES
- EO SEPS HAS NO  $\Delta V$  LIMIT WITHIN MISSION MODEL REQUIREMENTS
- SIGNIFICANT PENALTIES OCCUR FOR OPERATION THROUGH VAN ALLEN BELTS

# SPACE TRANSPORTATION SYSTEM ELEMENTS WITH SEPS



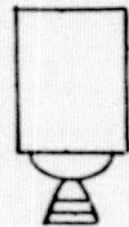
SHUTTLE



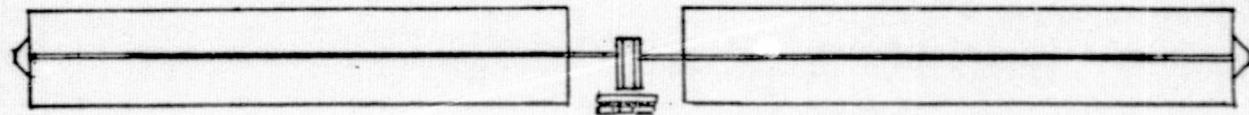
STANDARD KICK STAGE  
+ FAMILY OF SRMS



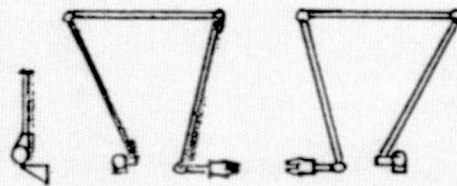
INTERIM  
UPPER STAGE



BASE LINE  
TUG



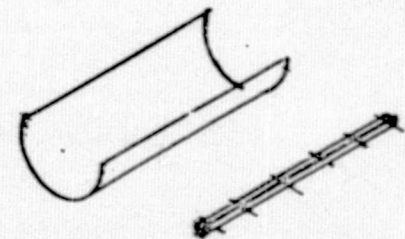
CORE SEPS



MAST/MANIPULATOR  
SYSTEM KIT



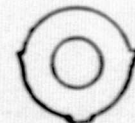
EO AVIONICS  
KIT



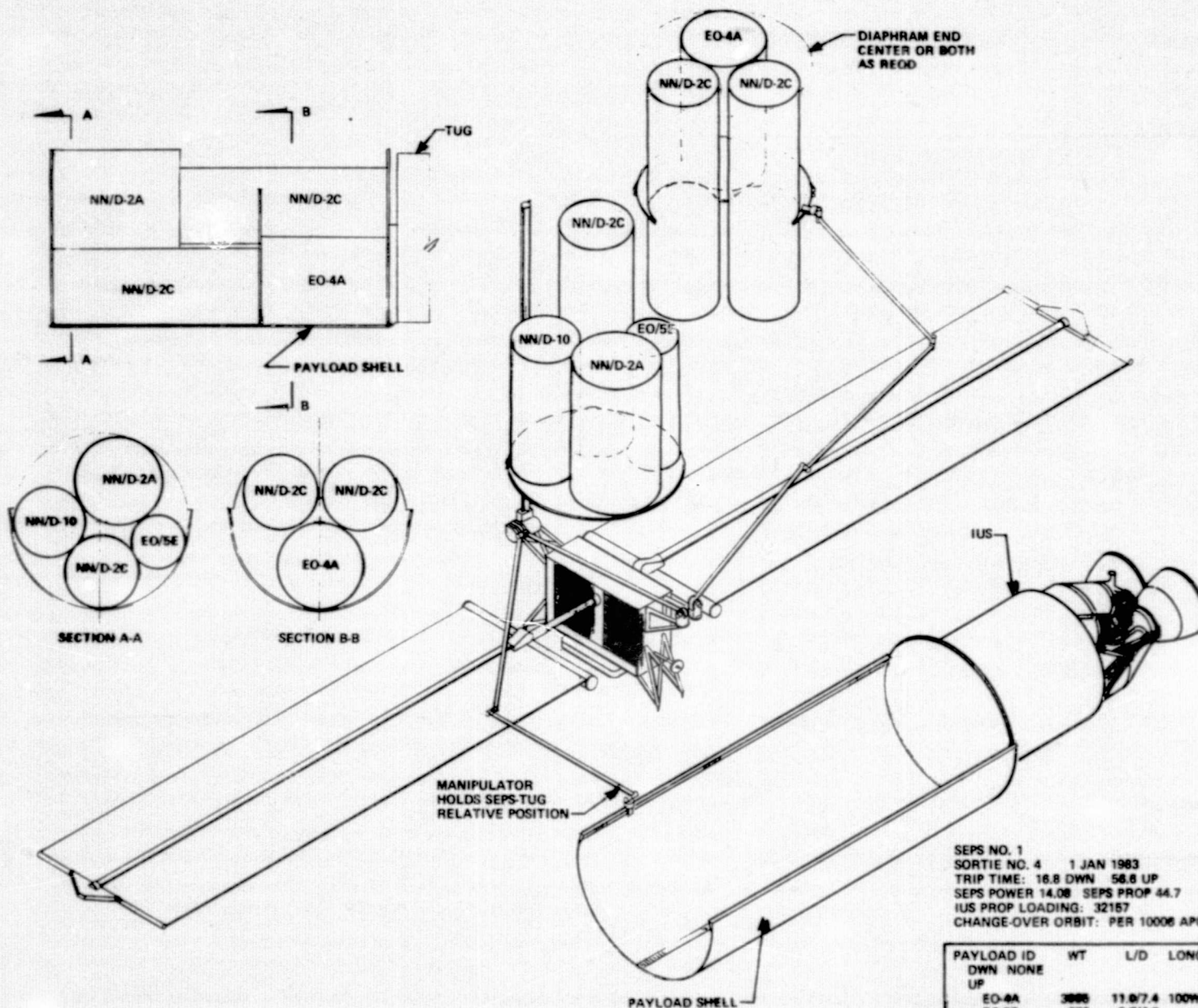
TRANSPORT SHELL &  
ORBITER INTERFACE  
LONGERON



STANDARD DIAPHRAGM  
& REPLENISHMENT KIT



SORTIE TAILORED  
DIAPHRAGMS

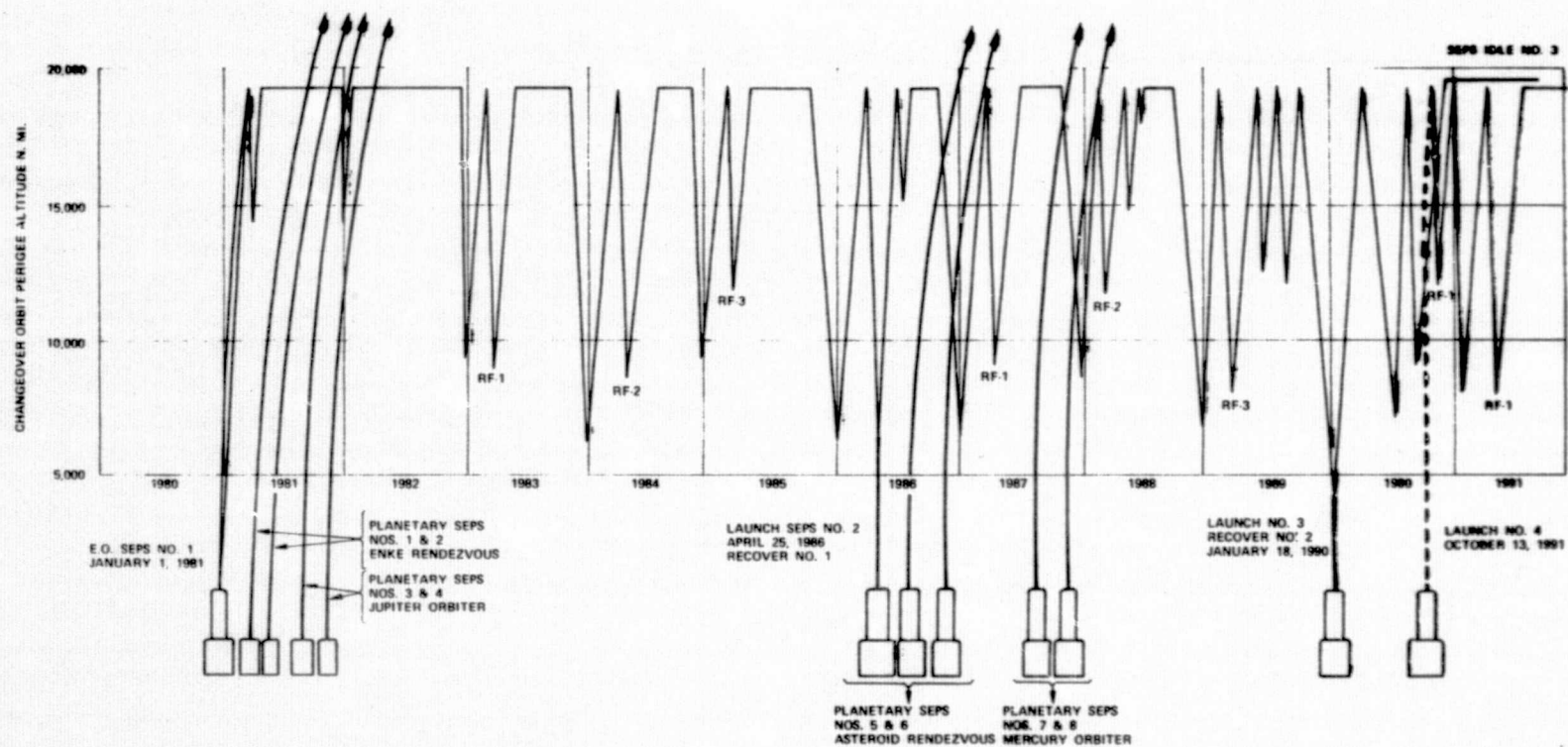


SEPS NO. 1  
 SORTIE NO. 4 1 JAN 1983  
 TRIP TIME: 16.8 DWN 58.6 UP  
 SEPS POWER 14.08 SEPS PROP 44.7  
 IUS PROP LOADING: 32157  
 CHANGE-OVER ORBIT: PER 10006 APO 25867 INC 4.2

PAYLOAD ID	WT	L/D	LONGITUDE DESCRIPTION
DWN NONE			
UP			
EO-4A	3086	11.0/7.4	100W SYNC EARTH OBS
EO-5E	878	9.7/4.7	- APPLICATION EXP.
NN/D-2C	974	17.9/6.3	N/A US DOM SAT C
NN/D-2C	974	17.9/6.3	N/A US DOM SAT C
NN/D-2C	974	17.9/6.3	N/A US DOM SAT C
NN/D-2A	1067	11.1/7.6	N/A US DOM SAT A
NN/D-10	807	10.3/6.0	140E GEOSYNC OPER MET SAT



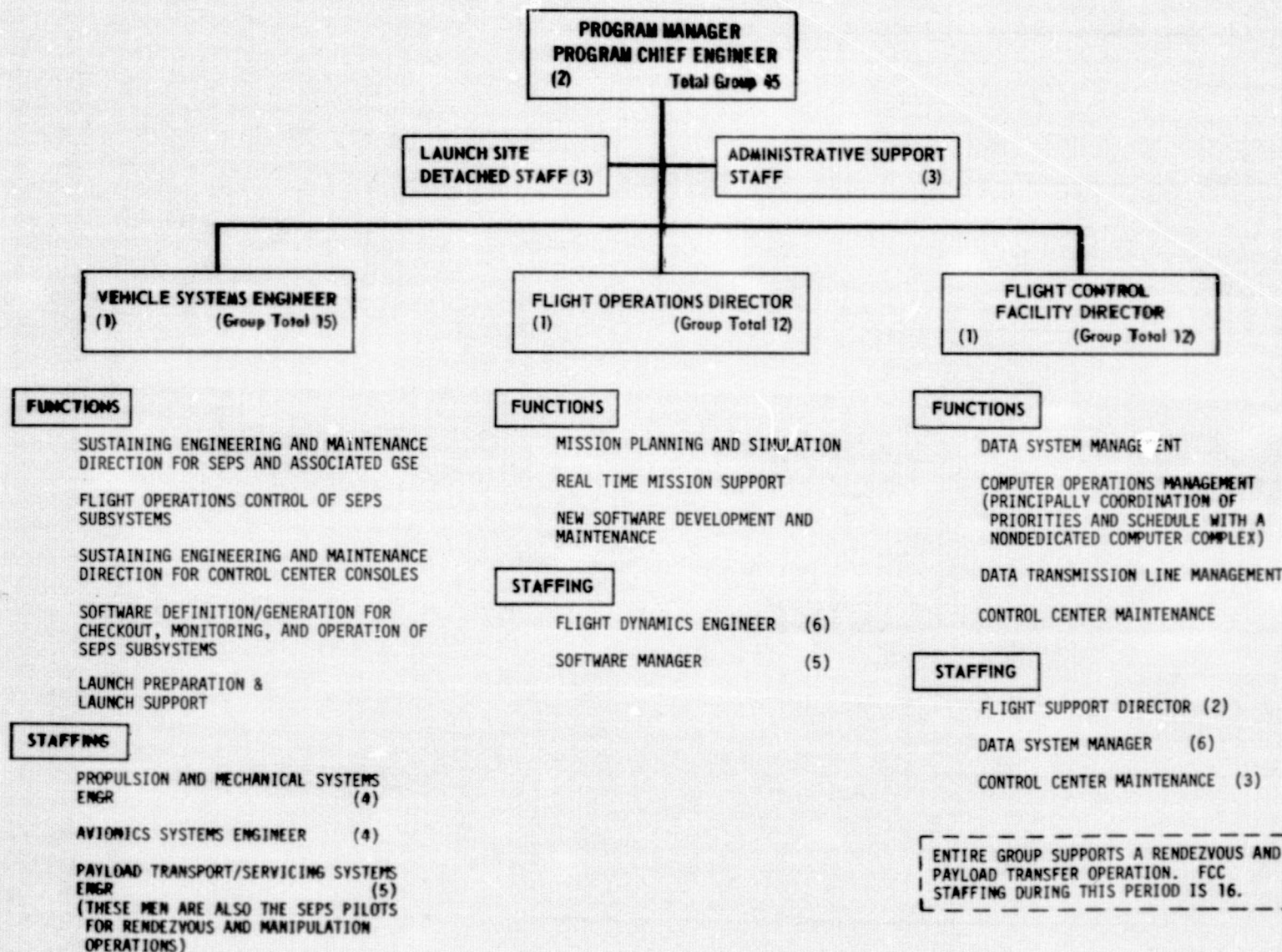
**SYSTEM OPERATIONAL PROFILE (30 FOOT BASELINE  
TUG + 25,000 SEPS WITH 20,000 THRUSTER LIFE - REFUELED**



SHUTTLE	15	19	22	28	27	35	34	32	32	30	32	34
SHUTTLE/TUG	0	6	2	8	11	11	10	8	4	0	9	8
SHUTTLE/ TUG/SEPS	0	2	1	2	2	2	3	2	4	4	5	2
	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991

NO. OF SHUTTLE FLIGHTS      340  
 NO. OF SHUTTLE/TUG FLIGHTS   83  
 NO. OF SHUTTLE/TUG/SEPS  
     FLIGHTS                      29  
 TOTAL STS FLIGHTS           452





# SEPS SUMMARY COSTS

NON-RECURRING	\$ 122.5 M
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PRODUCTION	137.9
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OPERATIONS	33.8
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TOTAL SEPS COSTS	<hr/> \$ 294.2 M
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# TRANSPORTATION COST EFFECTIVENESS COMPARISON

## FLIGHTS REQUIRING UPPER STAGES

COST ELEMENT (DOLLARS IN MILLIONS)	BLSTS	BLSTS + BLSEPS (20 KHR-REFUELED)
SHUTTLE FLIGHTS @ \$11.09	1508.	1353.
IUS EXPENDED @ \$5.17	103.	98.
IUS WITH KICK STAGE @ \$6.37	13.	13.
TUG RECOVERED FLTS @ \$.96	87.	75.
TUG RECOVERED EXPENDED KS @ \$2.16	15.	15.
TUG EXPENDED @ \$14.16	0.	0.
TUG AND KS EXPENDED @ \$15.36	92.	92.
SEPS SORTIES @ \$.89	--	26.
VEHICLE INVENTORY COST SEPS @ (VARIES WITH PRODUCTION)	105.	138.
TOTAL	1923.	1810.
\$ SAVED IN TRANSPORT COST	--	113.
SEPS DEVELOPMENT, OPERATIONS, START-UP, & REFURB. COST	102.	131.
TOTAL SYSTEM COST	2025.	1941.
NET \$ SAVED	--	84.

## EVALUATION CRITERIA FOR CHOICE OF SEPS CONFIGURATION

PROBLEM!!!

EVALUATE AGAINST:

A. MINIMUM TO MEET ABSOLUTE MISSION NEED?

OR

B. COST EFFECTIVENESS ONLY AGAINST A REFERENCE MISSION MODEL  
ESTABLISHED FOR AN STS WITHOUT SEPS

AND/OR

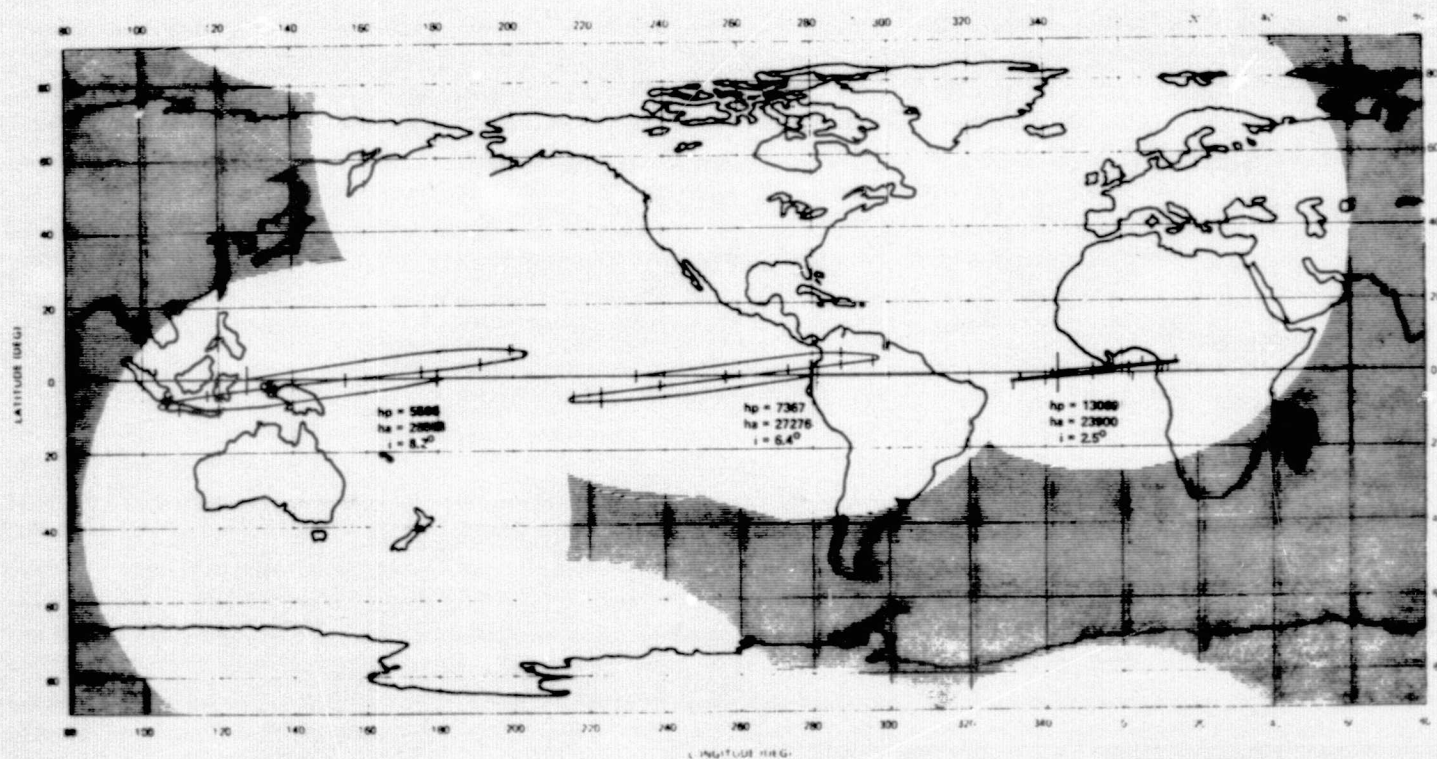
C. RECOGNIZABLE POTENTIAL VALUE OF FUNCTIONAL CAPABILITIES  
AND MISSIONS NOT IN PRESENT MISSION MODELS PLUS B FACTORS



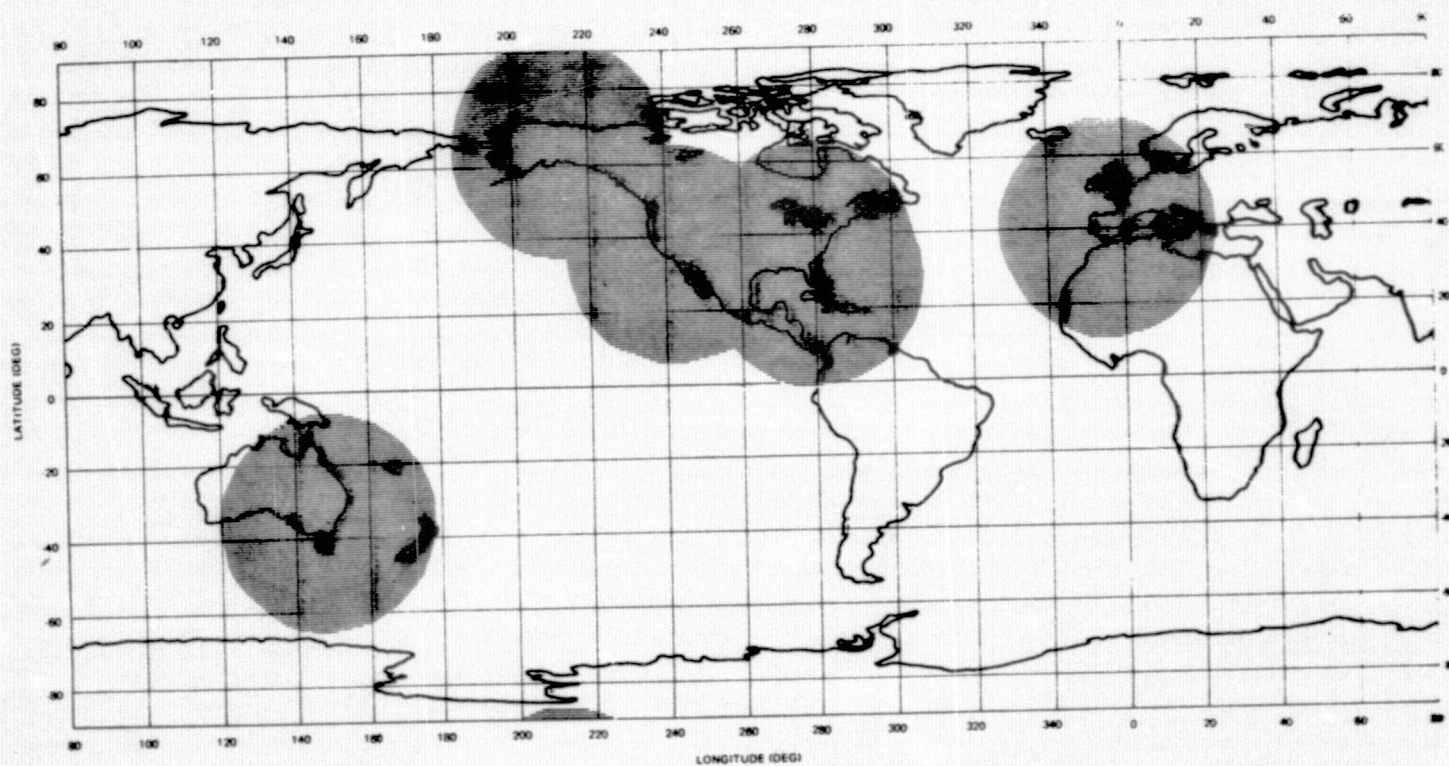
## CONCLUSIONS AND RECOMMENDATIONS

- o USE OF SEPS WITH THE STS ADDS SIGNIFICANTLY TO CAPABILITY AND RESULTS IN SIGNIFICANT RETURN ON E.O. INVESTMENT
- o THE MANIPULATOR/MAST SYSTEM WILL RESULT IN LOW OPERATIONAL COST AND MINIMUM IMPACT ON PAYLOADS. A MANIPULATOR SYSTEM IS RECOMMENDED FOR BASELINE SEPS
- o SCREEN POWER DIRECT FROM THE SOLAR ARRAYS WITH INHERENT  $I_{sp}$  OPTION IS RECOMMENDED
- o SEPS DEVELOPMENT AND OPERATIONS COSTS ARE ONLY SLIGHTLY INFLUENCED BY POWER LEVEL
- o HIGHER POWER SEPS ENHANCES TRANSPORTATION CAPABILITY

# STDN COVERAGE FOR 5586 NAUTICAL MILE ORBITAL ALTITUDES

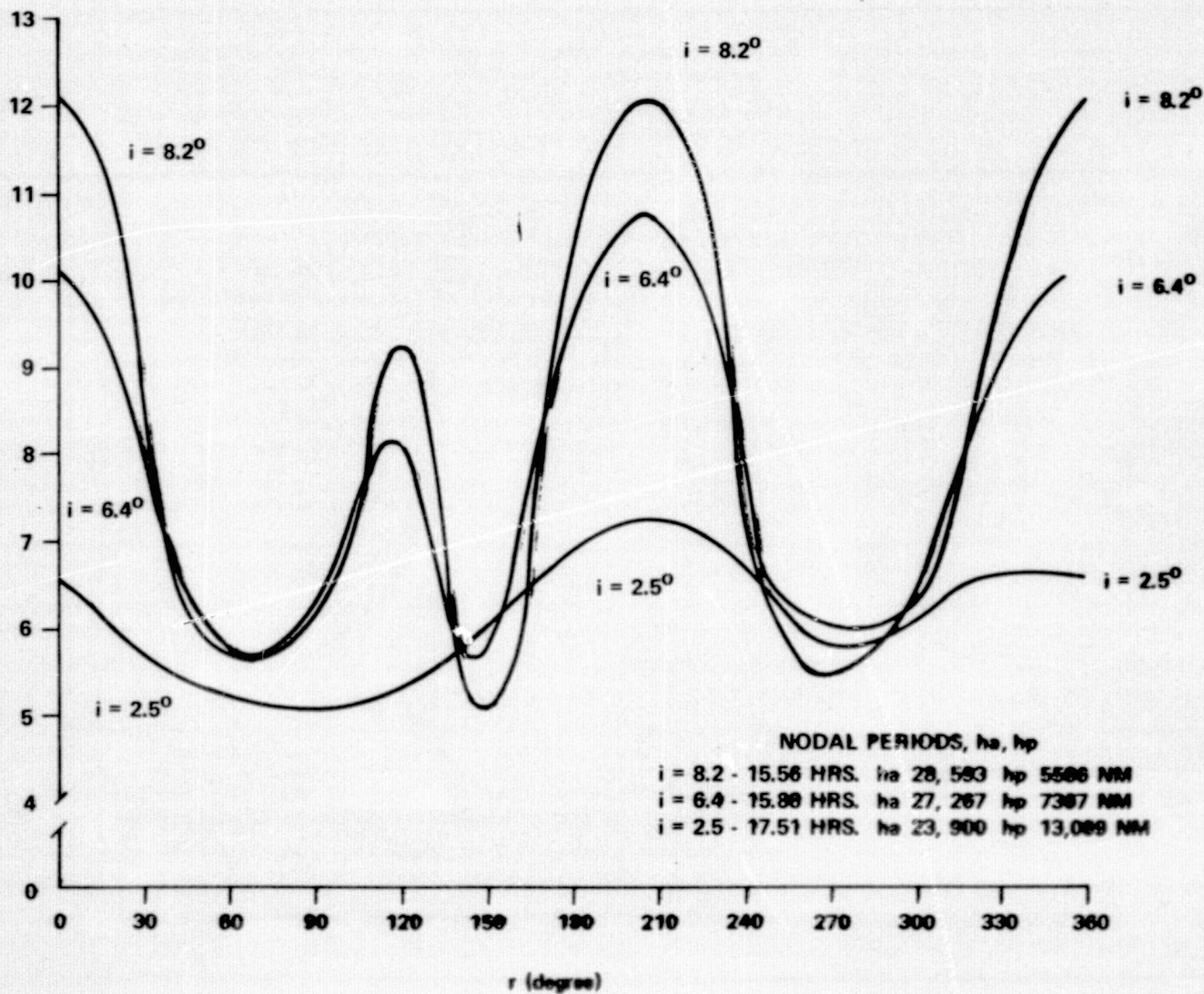






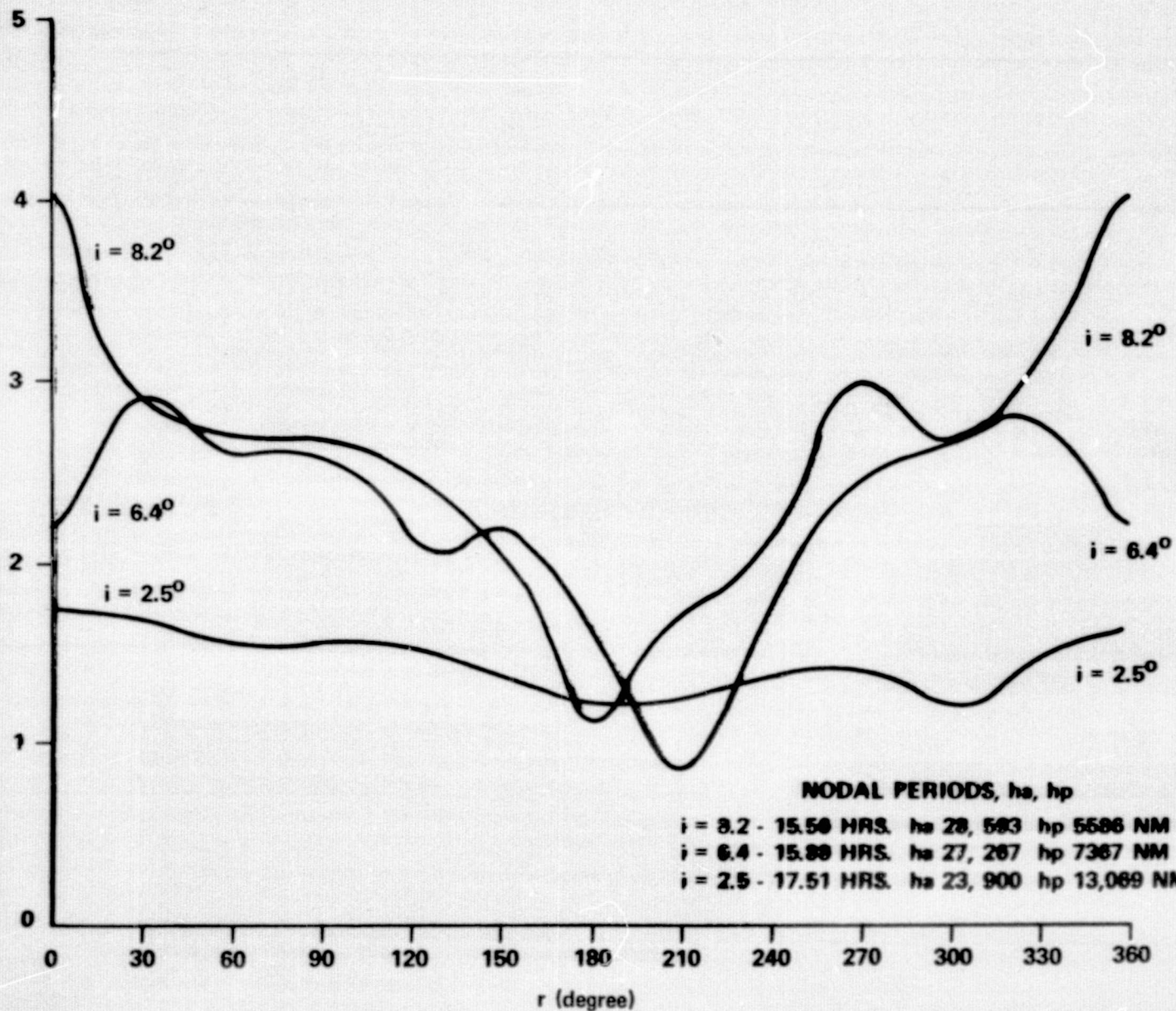
STDN COVERAGE FOR ORBITAL ALTITUDE 400 NM

MAXIMUM PERCENT  
OF ORBITAL PERIOD  
IN EARTH'S SHADOW





AVERAGE YEARLY PERCENT OF ORBITAL PERIOD IN EARTH'S SHADOW



**BASIC DIFFERENCES  
SHUTTLE-TUG ASCENT  
TO GEOSYNCH VERSUS ASCENT  
TO SEPS-TUG CHANGEOVER ORBIT**

**FOR TUG ONLY**

- SHUTTLE LAUNCH FROM KSC MAY OCCUR AT ANY TIME. TUG WAITS IN PARKING/PHASING ORBITS UNTIL EARTH ROTATES TARGET LONGITUDE TO PROPER RELATIVE POSITION.
- MAX WAIT TIME IN ORBIT  $\approx$  12 HOURS.
- TARGET LONGITUDE DICTATES WAIT TIME IN LOW ORBIT.
- TUG DESCENT BURN WAIT TIME  $\leq$  12 HOURS.

**FOR TUG + SEPS**

- SHUTTLE LAUNCH WINDOW ONCE PER DAY AT TIME DETERMINED BY SEPS ORBIT.
- FOR CIRCULAR SEPS ORBIT, TUG INITIATES ASCENT BURN ANYTIME PHASING IS PROPER.
- FOR ELLIPTICAL ORBITS, TUG MINIMUM ENERGY ASCENT/DESCENT WINDOWS EXIST ONCE PER SEPS ORBIT.



# LAUNCH-DELAY PENALTIES FOR INCLINED CHANGEOVER ORBITS

MINIMUM TUG  $\Delta V$  (2-WAY) = 6780 METERS/SECOND

$\Delta V$  PENALTY - METERS/SECOND

200

PARKING ORBIT  
160 x 160 N. MI.  
28.5° INCLINATION

100

ELLIPTICAL CHANGEOVER

CIRCULAR CHANGEOVER

0

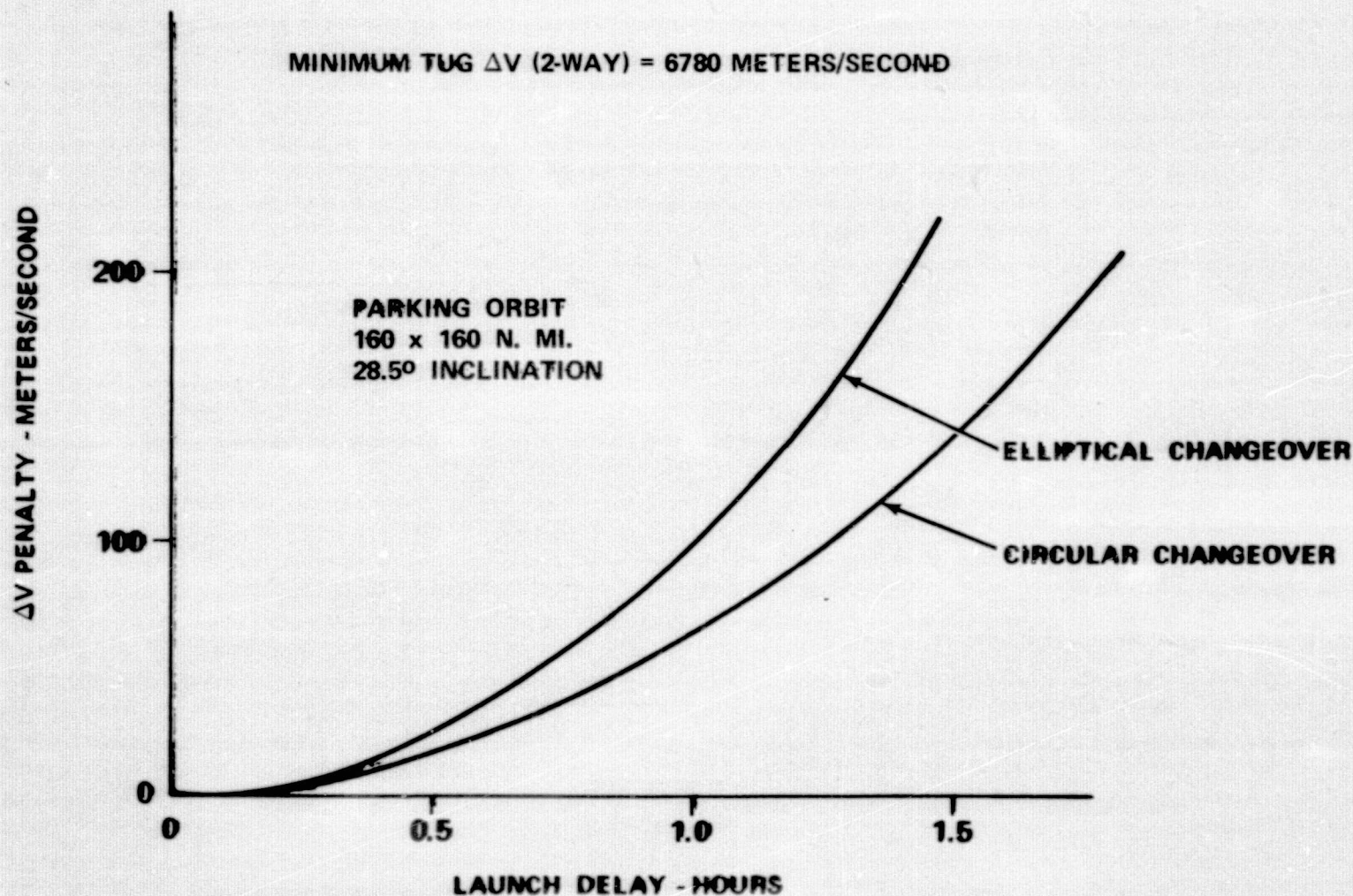
0

0.5

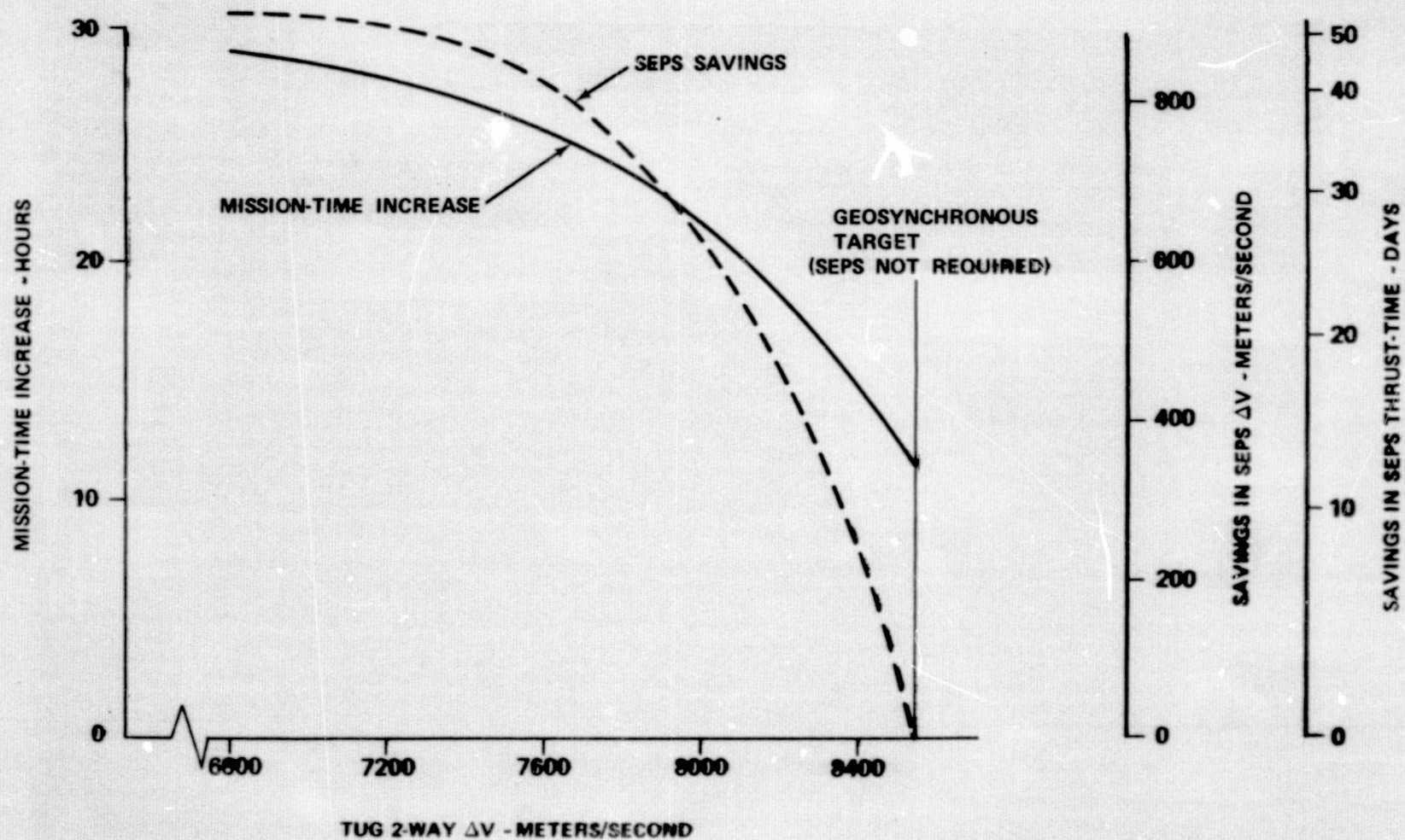
1.0

1.5

LAUNCH DELAY - HOURS



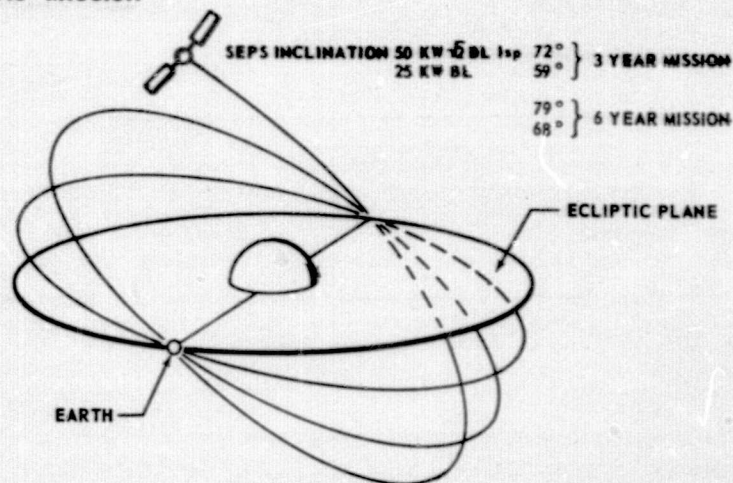
# MISSION-TIME INCREASE AND SEPS SAVINGS (WITH ELLIPTICAL CHANGEOVER ORBITS)





# OUT OF ECLIPTIC MISSION

## ADVANTAGES OF HIGHER POWER & isp



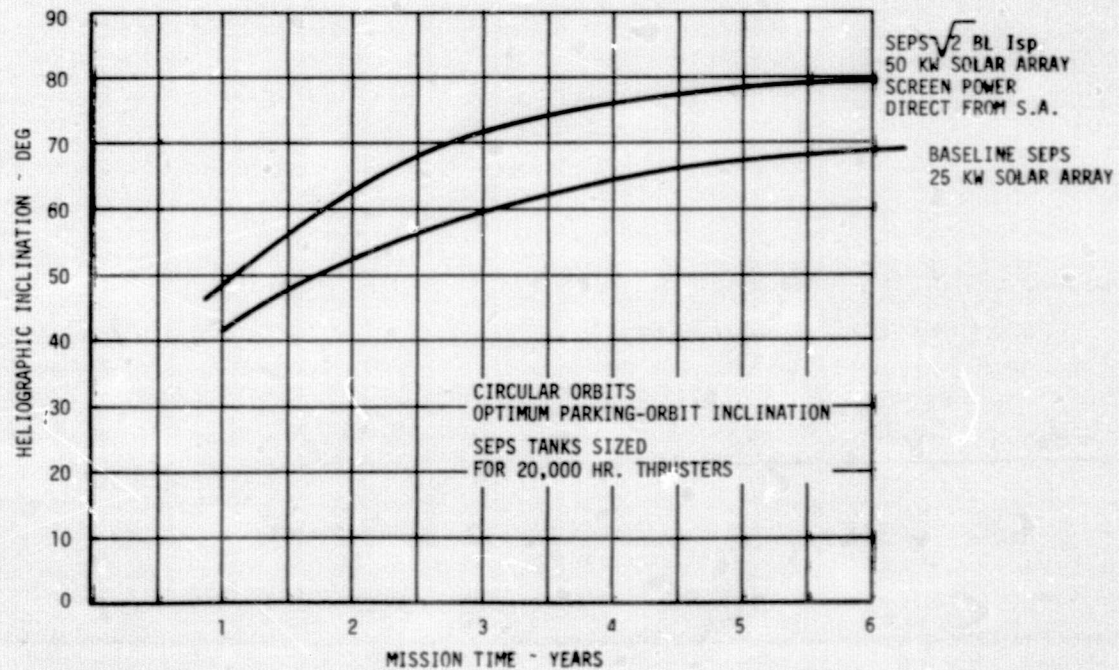
### SEPS

	25 KW BASELINE	50 KW $\sqrt{2}$ BL Isp
INERT MASS	1373 KG	1713 KG
PROPELLANT	2289 KG	2240 KG
BURN TIME	18955 HOURS	15534 HOURS
COAST TIME	7324 HOURS	10746 HOURS

### CENTAUR

	25 KW BASELINE	50 KW $\sqrt{2}$ BL Isp
INERT MASS	1859 KG	1859 KG
PROPELLANT	7722 KG	7431 KG
BURN TIME	258.90 SEC	249.15 SEC

NOTE: SUN'S EQUATORIAL PLANE INCLINED 7 DEGREES TO ECLIPTIC AND ORIENTED SO AS TO ADD DIRECTLY TO INCLINATION WITH RESPECT TO THE ECLIPTIC PLANE.



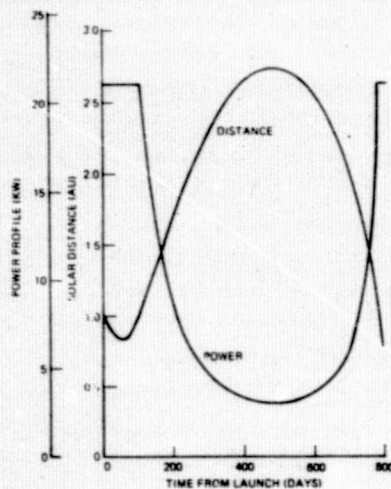
## DESIRABLE CHARACTERISTICS FOR PLANETARY MISSION FLEXIBILITY

- IMPROVED AVERAGE T/W RATIO
  - INCREASED SOLAR ARRAY AREA & HIGHER KW/KG
  - IMPROVED POWER PROCESSOR EFFICIENCY AND/OR SCREEN POWER DIRECT FROM ARRAY
  - FULLER UTILIZATION OF THRUSTERS INHERENT CAPABILITIES
  
- OPTION TO OPERATE AT HIGH OR LOW  $I_{sp}$  TO MATCH MISSION REQUIREMENTS
  
- RESERVE POWER TO SUPPORT PAYLOADS AT EXTRUDED DISTANCES

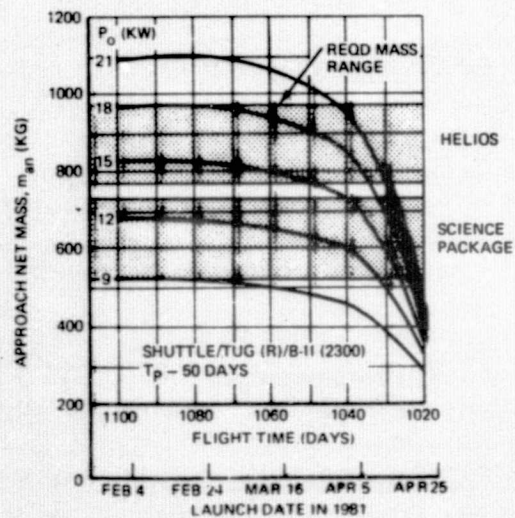
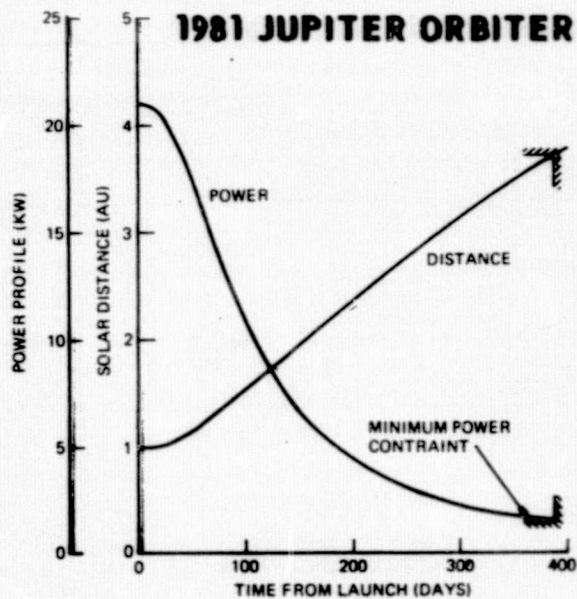


# REVIEW OF TYPICAL PLANETARY MISSIONS FOR SEPS

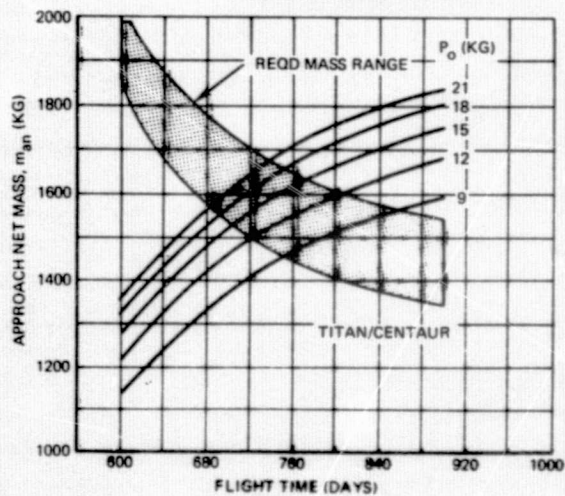
## 1981 ENCKE RENDEZVOUS



## 1981 JUPITER ORBITER



PL-26(2) 1981

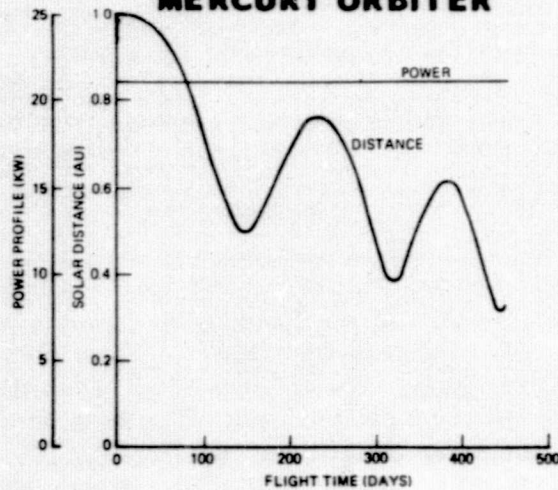


PL-19(2) 1981

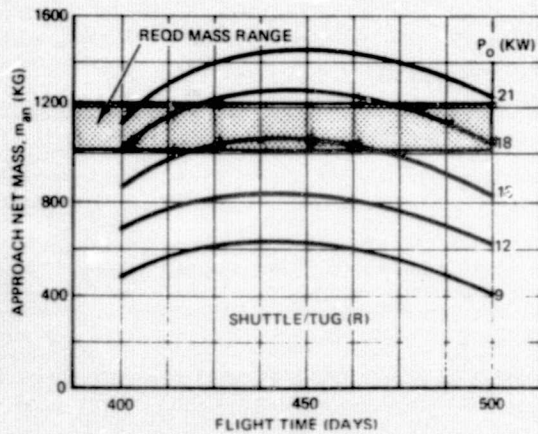
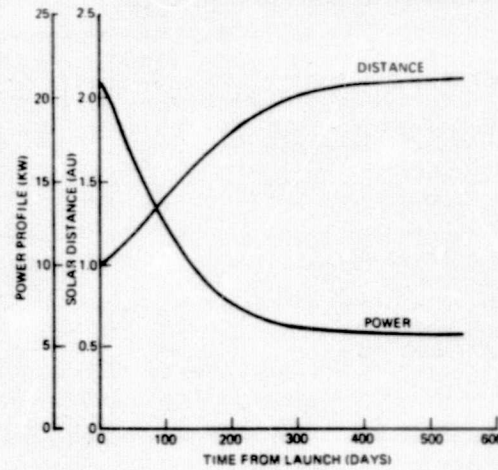
# REVIEW OF TYPICAL PLANETARY MISSIONS FOR SEPS

(CONTINUED)

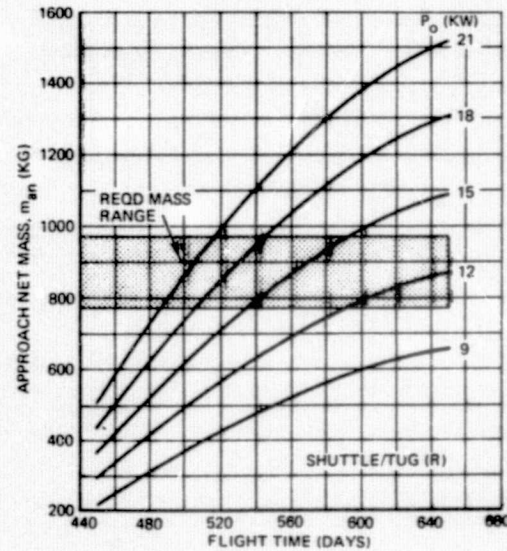
## MERCURY ORBITER



## METIS RENDEZVOUS



PL-13(2) 1987

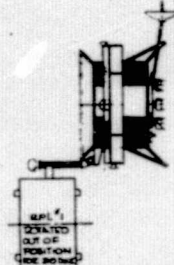
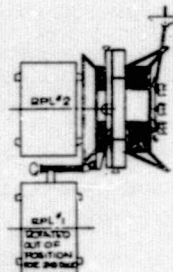
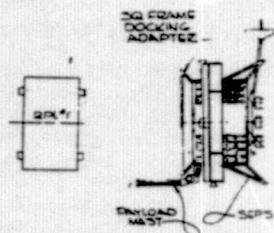
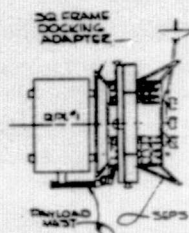


PL-28(2) 1986

## TRADE STUDIES AND TECHNOLOGY ASSESSMENTS

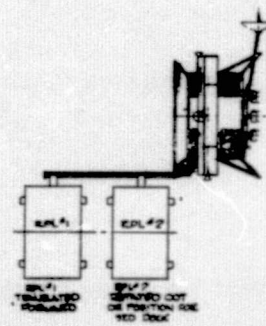
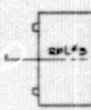
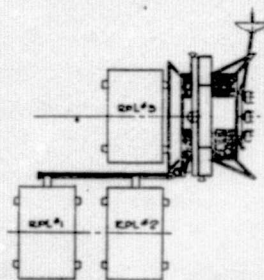
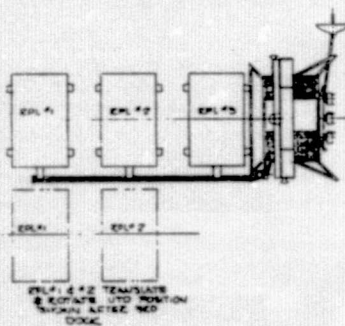
- o PAYLOAD TRANSFER AND SERVICING SUBSYSTEM
- o RENDEZVOUS N&G AND SENSORS
- o TSS TECHNOLOGY ASSESSMENT





DOCK & ATTACH PAYLOAD TO EXTENDABLE MAST  
BY DRIVING ARTICULATED LEGS TO TRANSLATE  
DOCKING FRAME TOWARD MAST CRUISE TO NEXT  
PAYLOAD

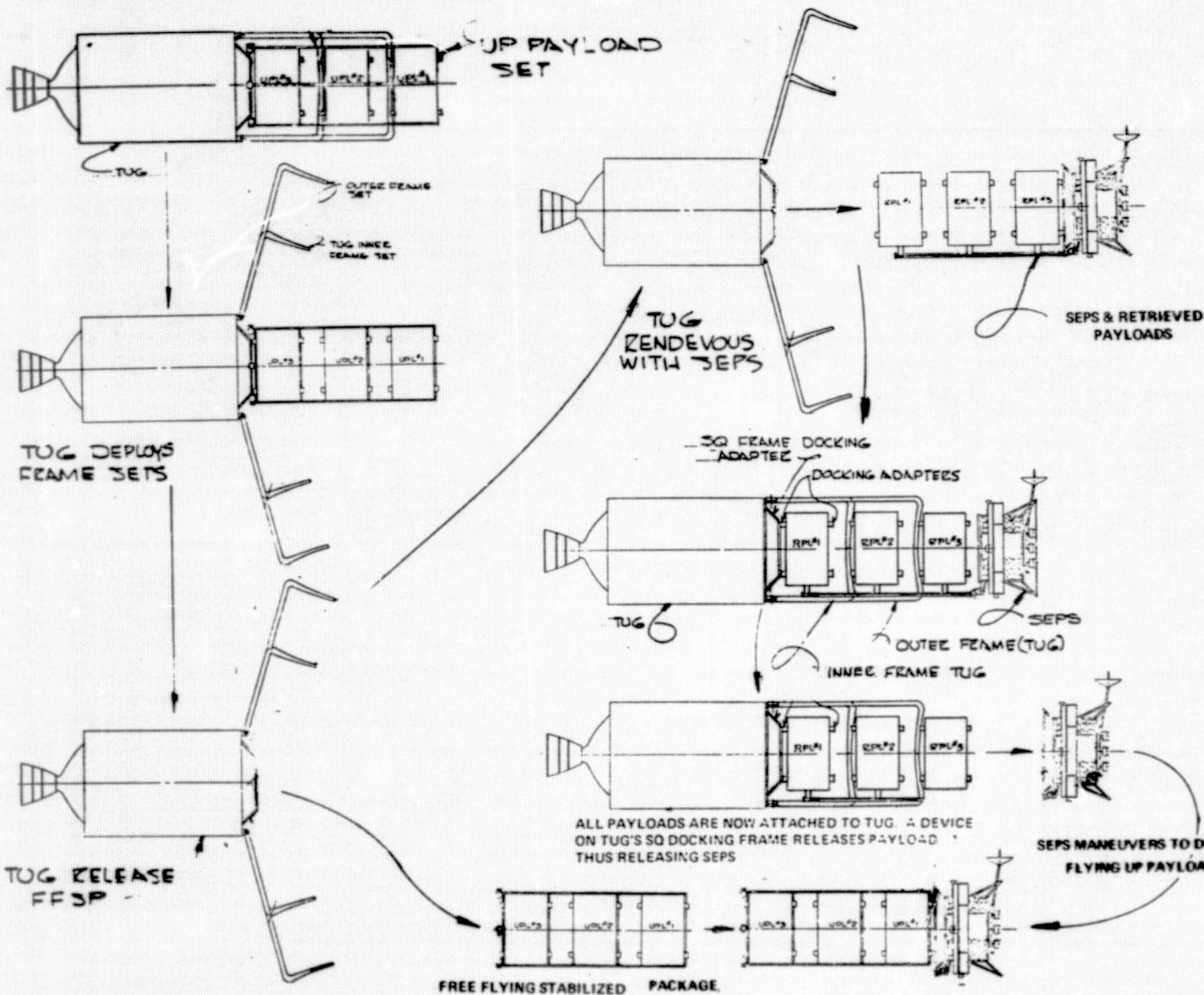
DOCK WITH NEXT PAYLOAD AFTER ROTATED 1ST  
PAYLOAD 180° TO CLEAR DOCKING FRAME



EXTEND MAST ATTACH #3 PAYLOAD TO  
MAST ROTATE #1 & #2 INTO FLIGHT  
POSITION

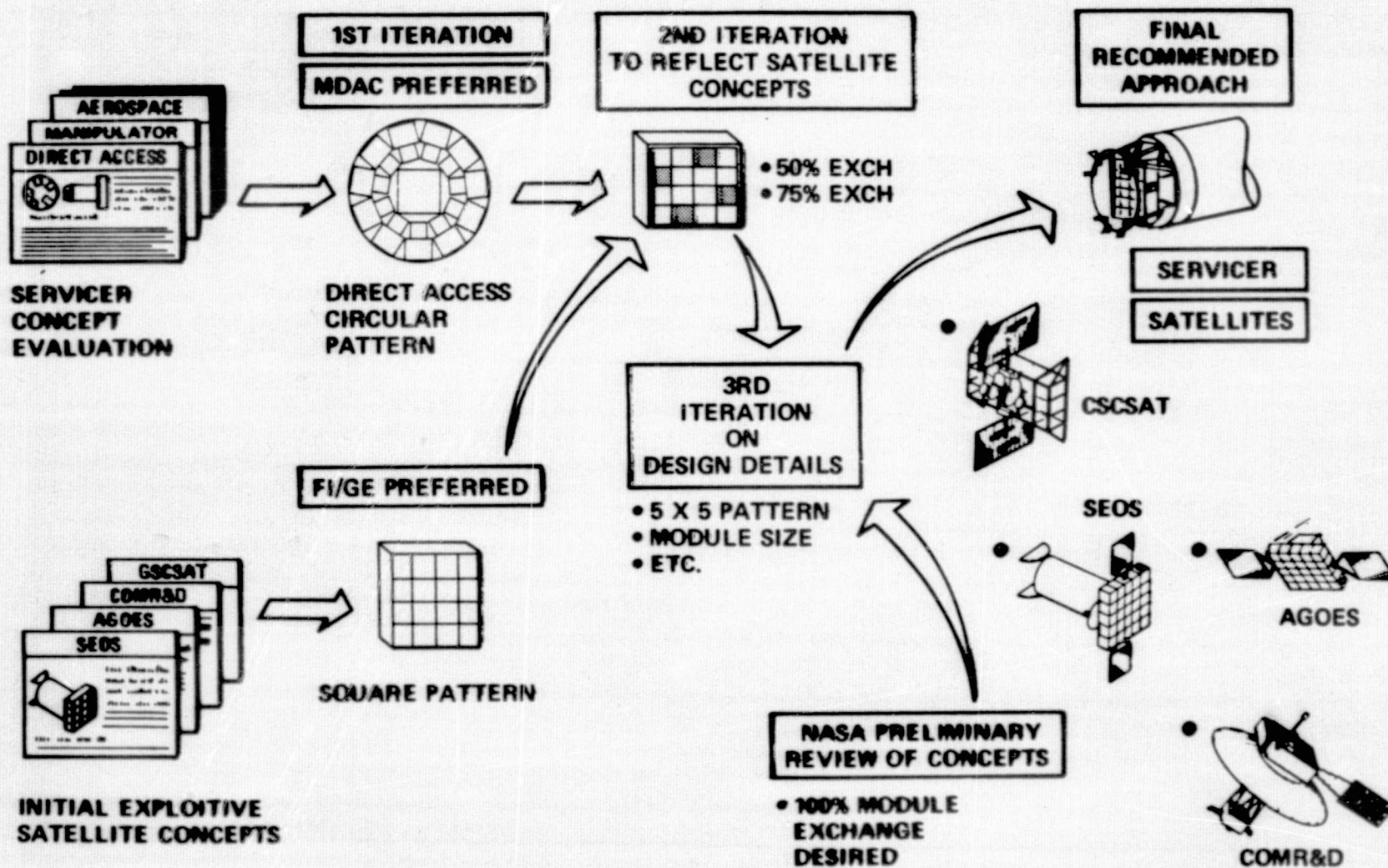
EXTEND MAST ROTATE #2 PAYLOAD 180° TO CLEAR  
DOCKING FRAME DOCK WITH #3 PAYLOAD

# PAYLOAD RETRIEVAL SEQUENCE



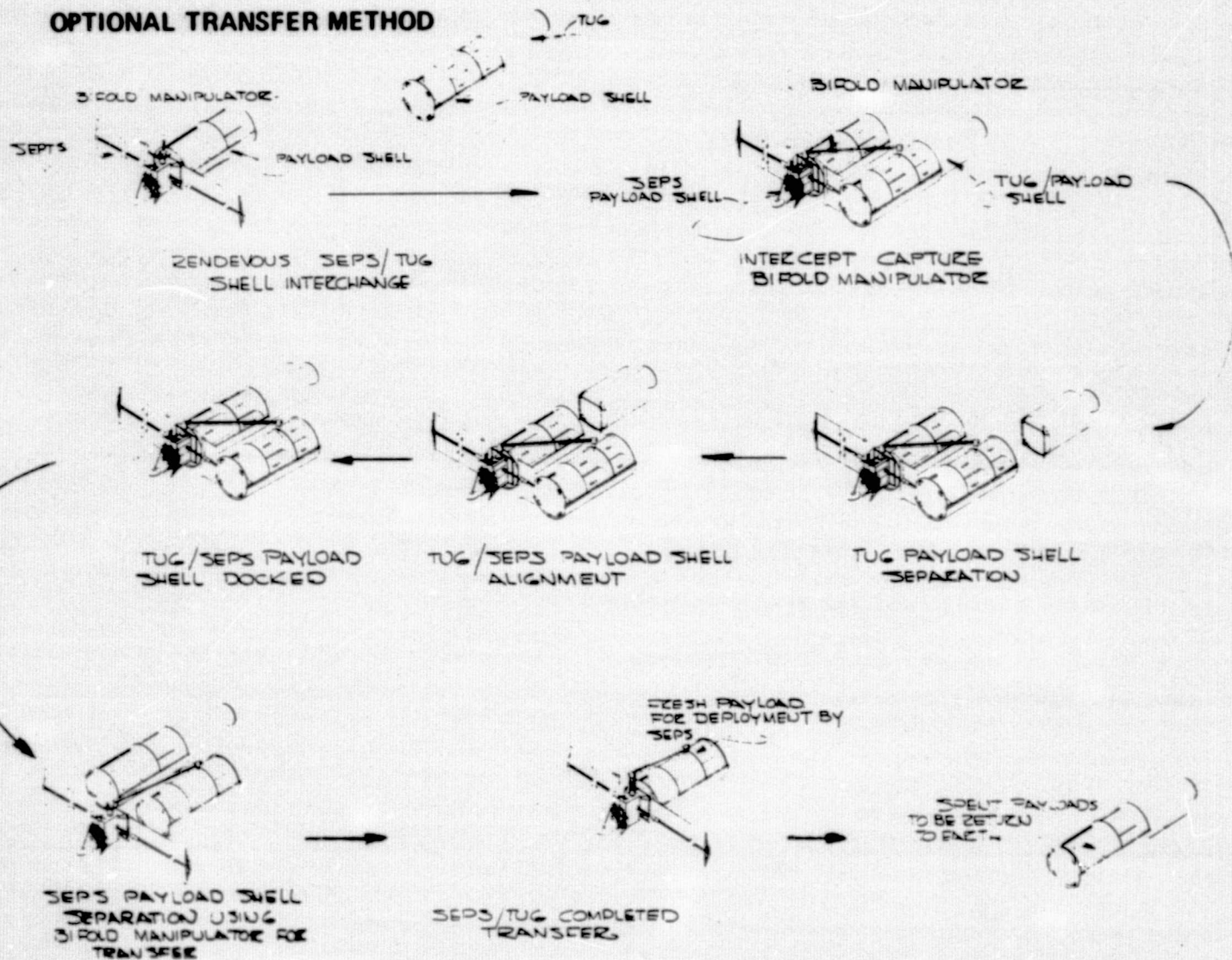


# SERVICER CONCEPT EVOLUTION

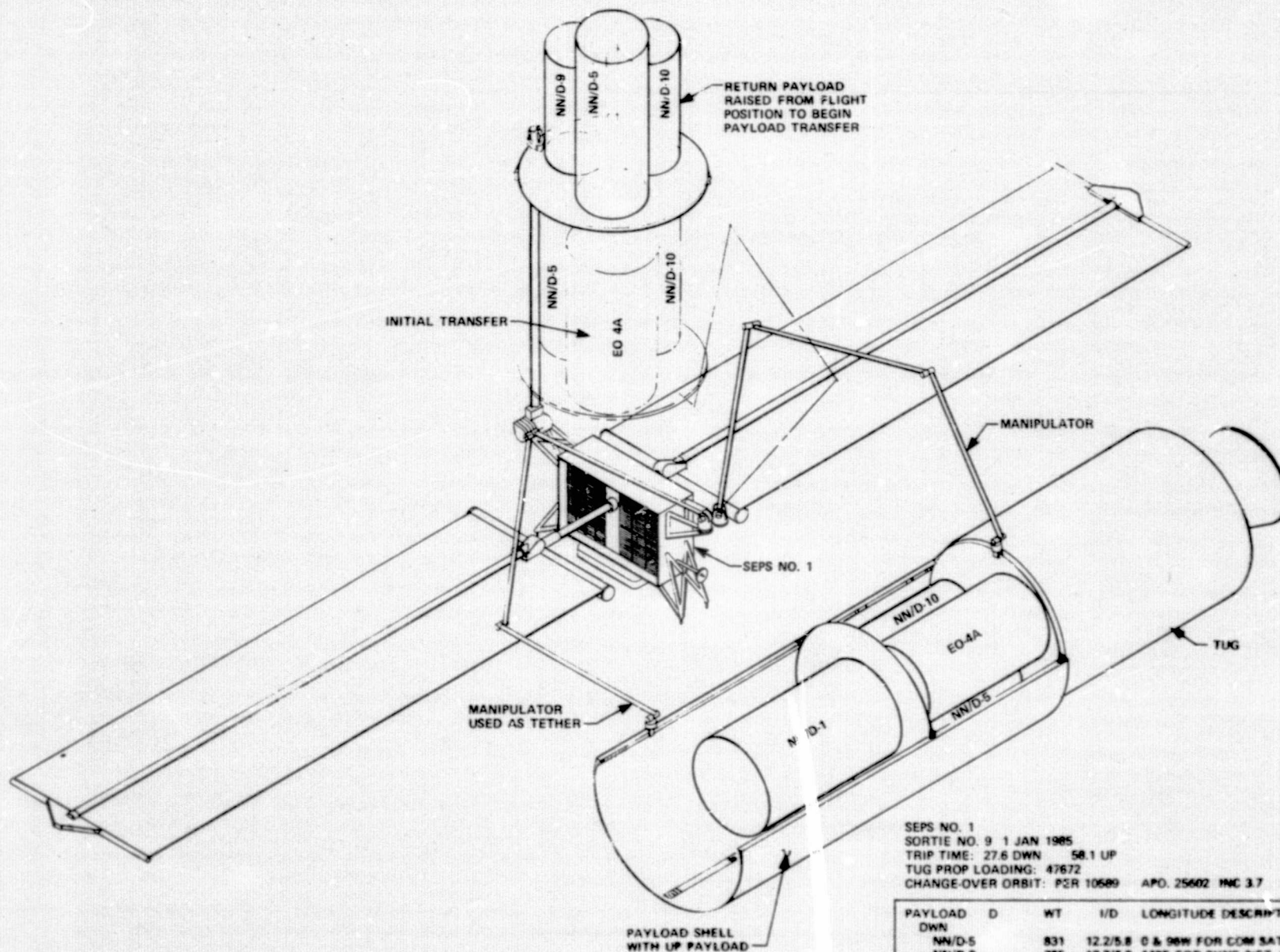




# OPTIONAL TRANSFER METHOD



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SEPS NO. 1  
 SORTIE NO. 9 1 JAN 1985  
 TRIP TIME: 27.6 DWN 58.1 UP  
 TUG PROP LOADING: 47672  
 CHANGE-OVER ORBIT: P2R 10689 APO. 25602 INC 3.7

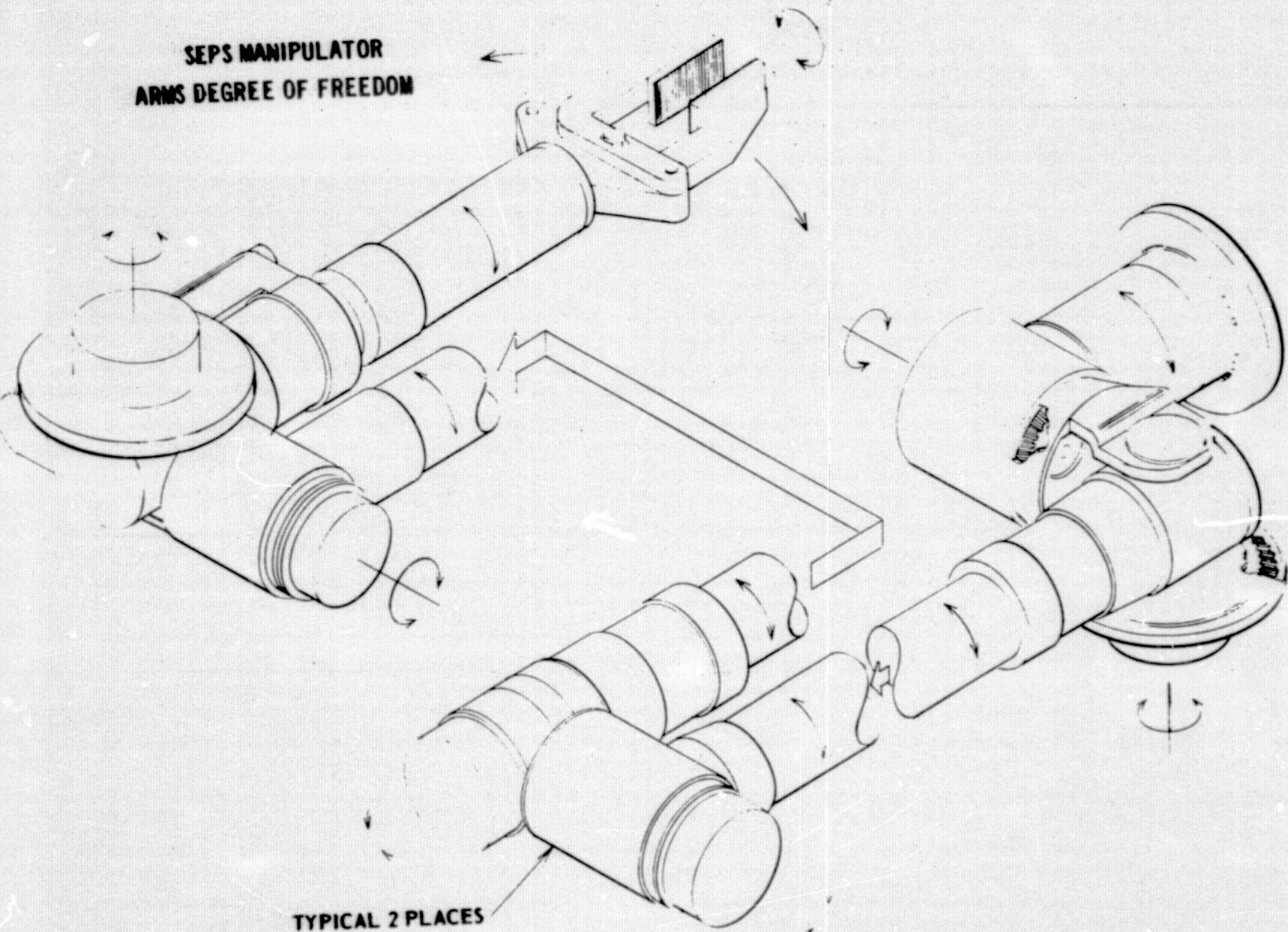
PAYLOAD	D	WT	I/D	LONGITUDE	DESCRIPTION
DWN					
NN/D-5		831	12.2/5.8	0 & 96W	FOR COM SAT A
NN/D-9		765	10.3/6.0	140E	FOR SYNC MET. SAT.
NN/D-10		765	10.3/6.0	140E	GEOSYNC OPER MET. SAT.
UP					
EO-4A		3085	11.0/7.4	100W	SYNC. EARTH OBS.
NN/D-1		4498	12.2/8.3	40W & 180W	INT. COM SAT
NN/D-5		982	12.2/5.8	0 & 96W	FOR COM SAT B
NN/D-10		807	10.3/6.0	140E	GEOSYNC OPER MET SAT



# PAYLOAD SUPPORT, HANDLING & SERVICING CONCEPT COMPARISON

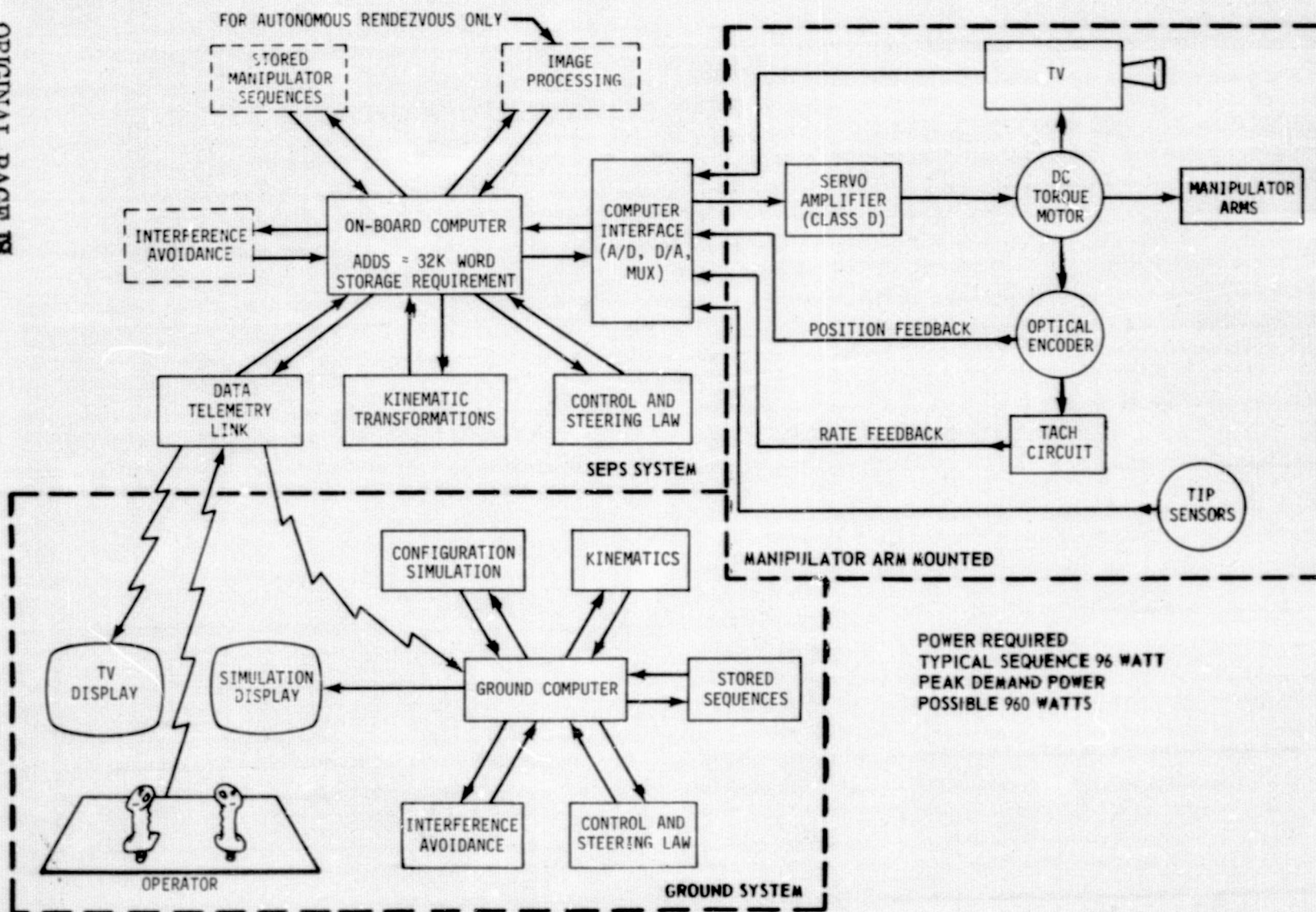
ARTICULATED DOCKING FRAME & PAYLOAD SUPPORT STRUCTURE	EXTENDABLE BOOM AND SIMPLIFIED MANIPULATOR	PAYLOAD MAST AND MANIPULATOR SYSTEM
<p>ADVANTAGES</p> <ul style="list-style-type: none"> <li>● SIMPLEST ONBOARD SOFTWARE</li> </ul>	<p>ADVANTAGES</p> <ul style="list-style-type: none"> <li>● MODERATE ONBOARD SOFTWARE REQUIREMENT</li> <li>● SIMPLEST PAYLOAD TRANSFER FUNCTION</li> </ul>	<p>ADVANTAGES</p> <ul style="list-style-type: none"> <li>● GREATEST INHERENT CAPABILITY FOR PAYLOAD SERVICES AND MAINTENANCE</li> <li>● MINIMIZES DESIGN CONSTRAINTS ON PAYLOADS</li> <li>● SIMPLEST AND MOST FLEXIBLE INFLIGHT OPERATION</li> <li>● SIMPLEST GPME &amp; TUG PAYLOAD INTEGRATION FUNCTION</li> <li>● HIGHEST MISSION SUCCESS PROBABILITY</li> </ul>
<p>DISADVANTAGES</p> <ul style="list-style-type: none"> <li>● MOST COMPLEX FLIGHT OPERATION</li> <li>● MOST COMPLEX FLIGHT HARDWARE</li> <li>● LIMITED GPME - REQUIRES TAILORING OF TUG MISSION EQUIPMENT &amp; ORBITER TO PL ADAPTERS FOR EACH SORTIE</li> <li>● EITHER SERIOUS PL DESIGN CONSTRAINT OR VERY LIMITED SERVICING ABILITY</li> <li>● NOT ADAPTABLE TO UNFORESEEN OR UNPLANNED MISSION EVENTS</li> <li>● COMPONENTS REQUIRING POSITIONING &amp; FEEDBACK INFO EXCEED OTHER SYSTEMS</li> </ul>	<p>DISADVANTAGES</p> <ul style="list-style-type: none"> <li>● LIMITED SERVICING AND ONORBIT MAINTENANCE ABILITY</li> <li>● INTERMEDIATE ADAPTABILITY TO UNPLANNED MISSION EVENTS</li> </ul>	<p>DISADVANTAGES</p> <ul style="list-style-type: none"> <li>● ONBOARD SOFTWARE REQUIRES ~ 32K WORD MEMORY STORAGE</li> </ul>

SEPS MANIPULATOR  
ARMS DEGREE OF FREEDOM



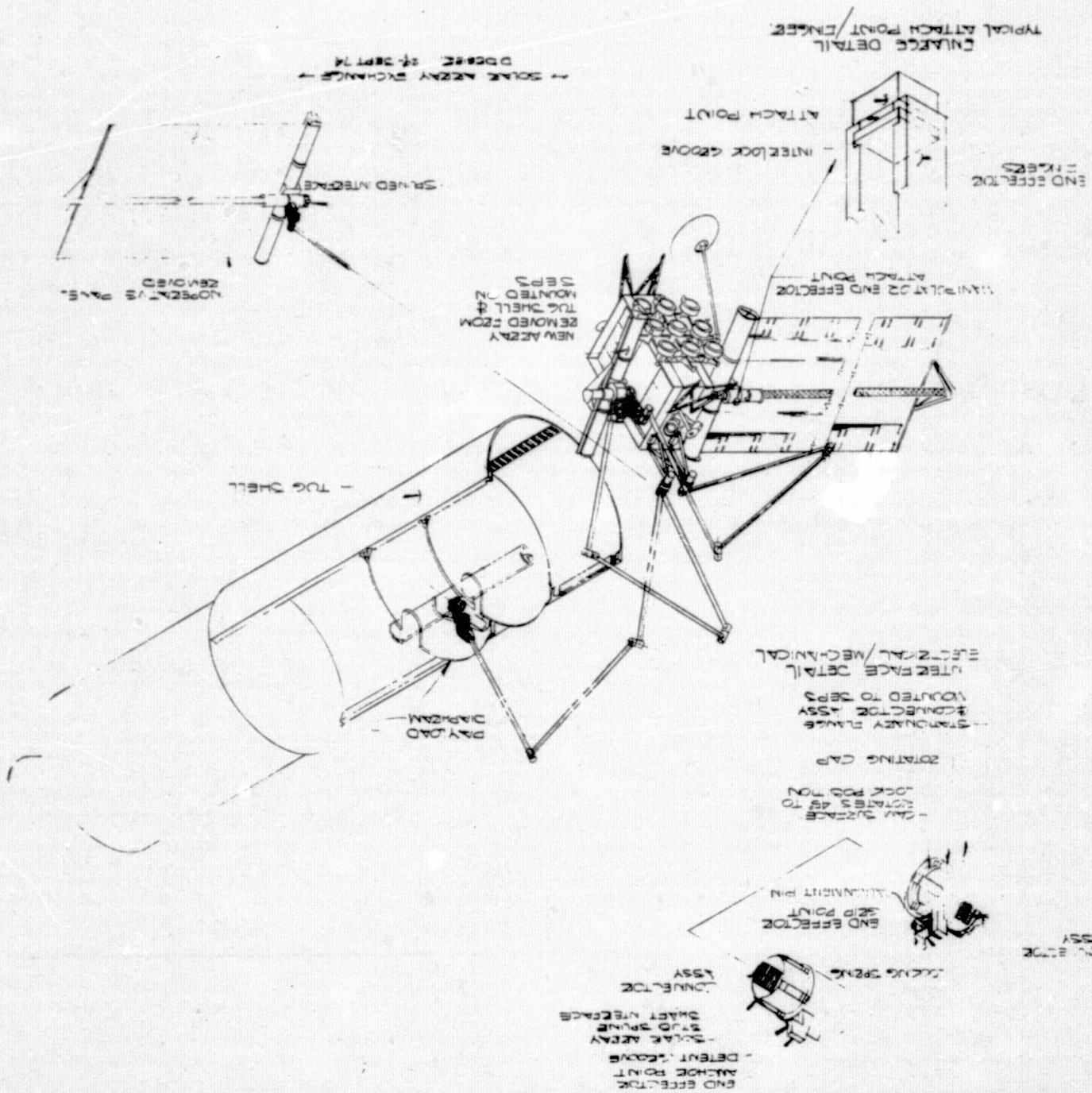


# MANIPULATOR SYSTEM SCHEMATIC

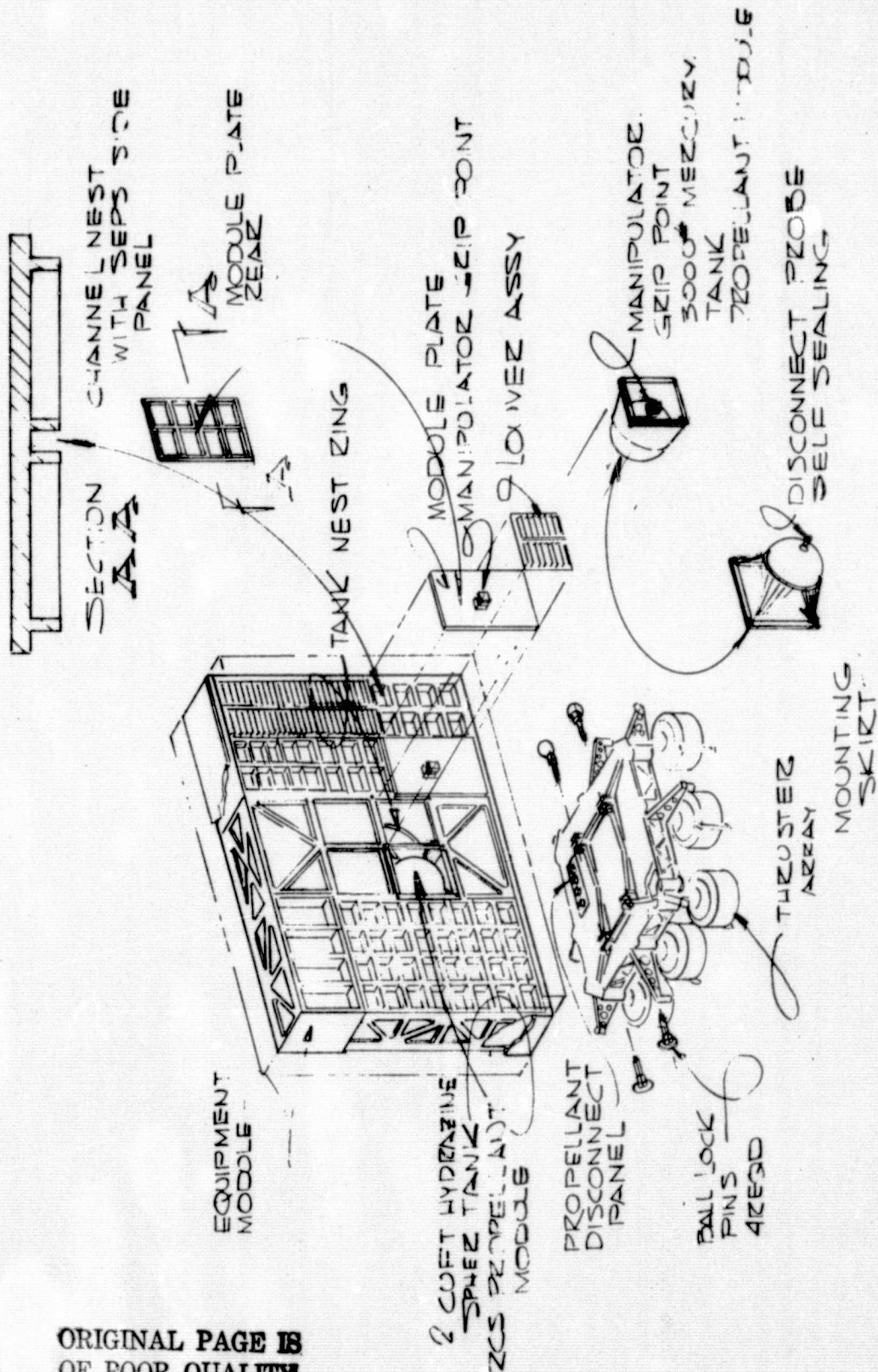




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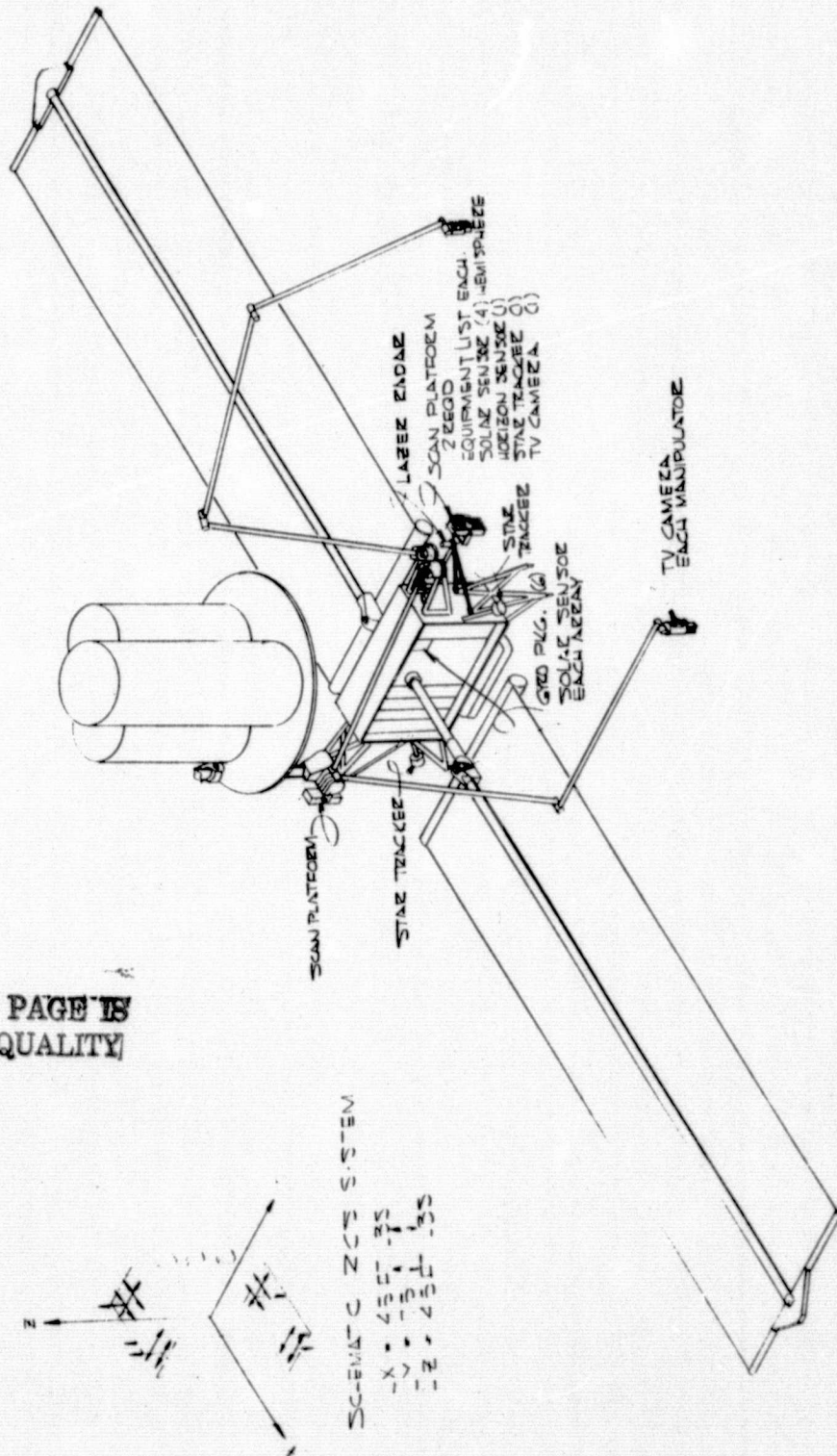
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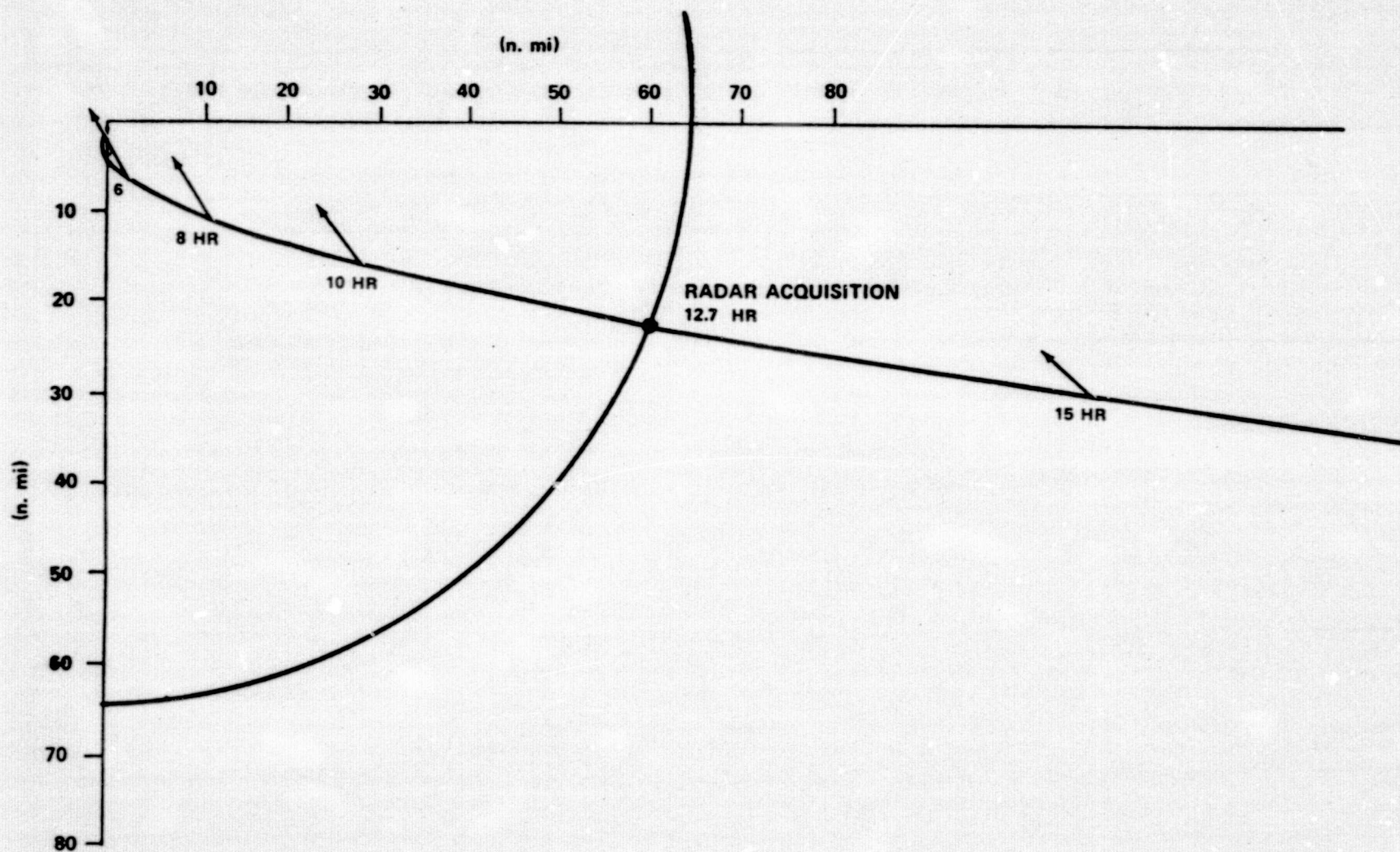


26 SEPT 74 D. OCE GR.

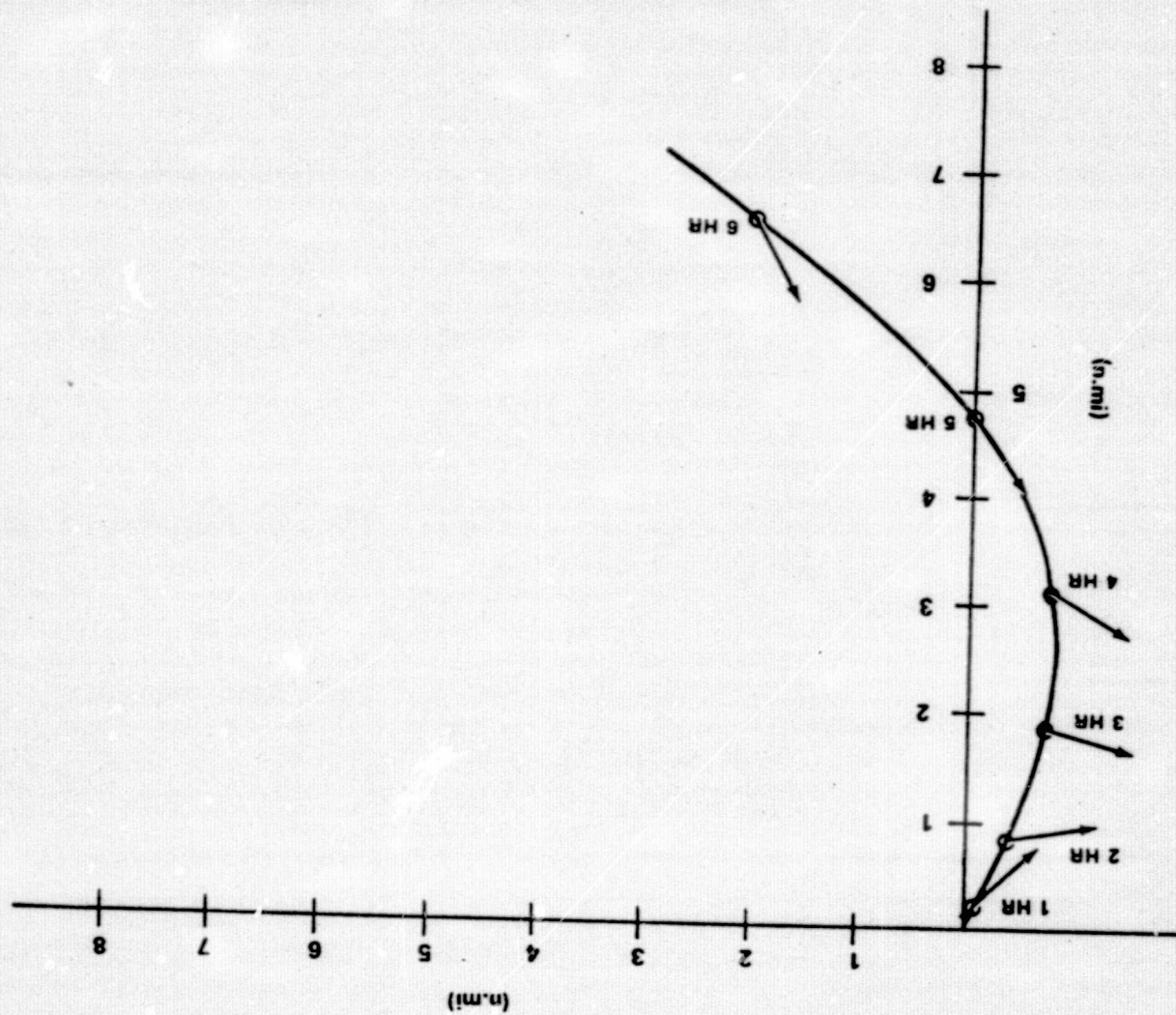


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# ATTITUDE CONTROL REQUIREMENTS

## ● BASIC - MAN-IN-THE-LOOP MANEUVERING

### ● ACCURACY

ATTITUDE  $\pm 0.1$  DEG  
RATE  $\pm .002$  DEG/SEC

### ● ACCELERATION CAPABILITY (LOADED)

TRANSLATION  $10^{-3}$  FT/SEC<sup>2</sup>  
ROTATION  $1.5 \times 10^{-5}$  RAD/SEC<sup>2</sup>

### ● IMPLIED FORCES

THRUST 0.5 LB  
PITCH TORQUE .16 FT LB  
ROLL & YAW TORQUE 0.82 FT LB

# ATTITUDE SENSORS

● RATE GYROS	(6 IN DODECAHEDRON)
● SOLAR SENSORS	(10)
● HORIZON SENSORS	(2)
● STAR TRACKERS	(4)
● TV CAMERAS	(4)
● LASER RADAR	(1)



## ASSESSMENT OF SUPPORTING TECHNOLOGY BASE

- THRUSTERS HAVE THE INHERENT ABILITY TO OPERATE OVER VOLTAGE RANGES OF LESS THAN 800V TO MORE THAN 2800V AND BEAM CURRENTS CORRESPONDING TO .5 TO MORE THAN 4 AMP IN A 30 CM THRUSTER

- SOLAR ARRAYS ARE BOTH FEASIBLE AND DESIRABLE  
DIRECT SOURCES OF THRUSTER BEAM POWER

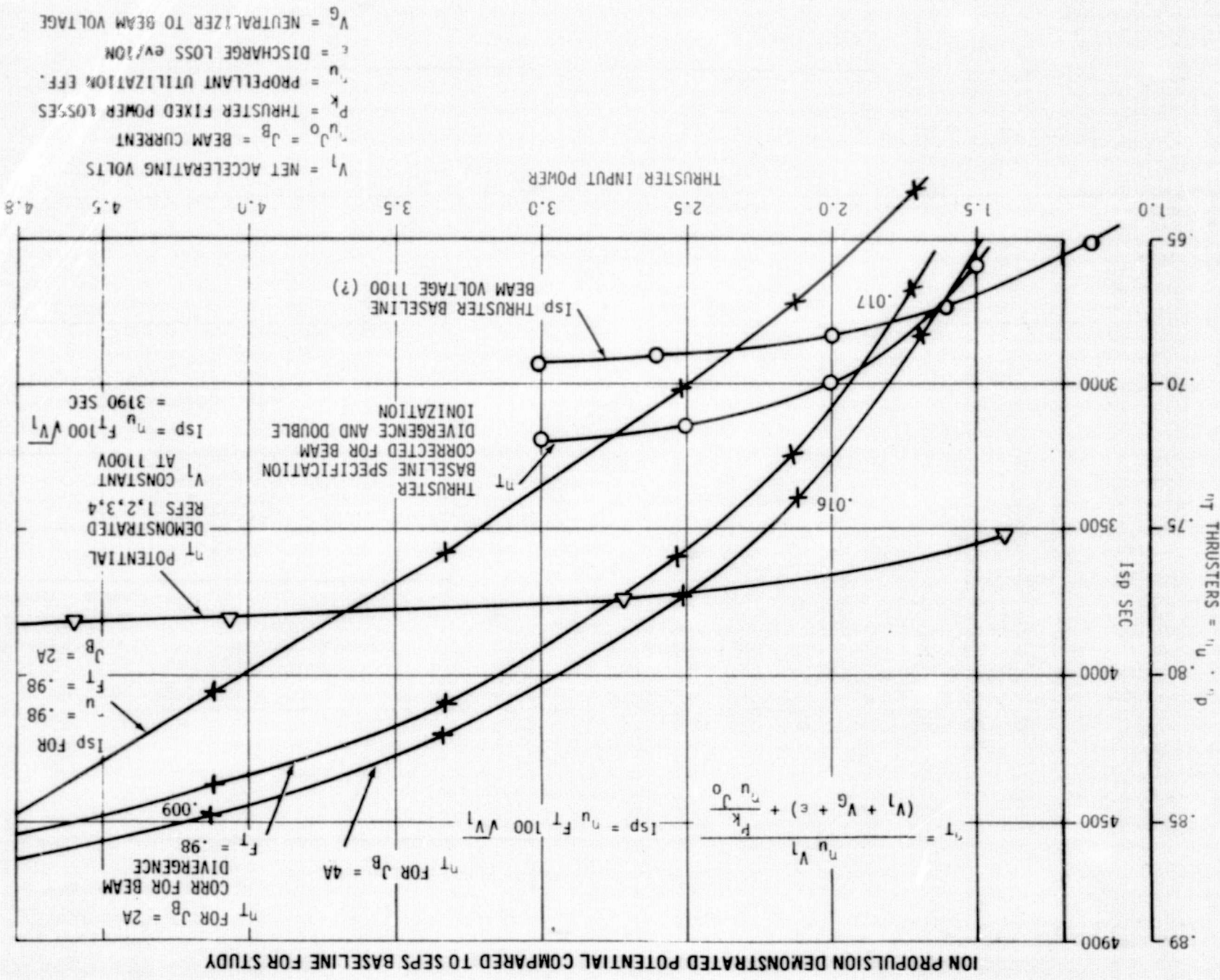
- HIGHER VOLTAGE SOLAR ARRAYS ARE FEASIBLE AND DESIRABLE

- POTENTIAL EXISTS FOR LOWER COST AND HIGHER RELIABILITY SOLAR ARRAYS

- HIGHER VOLTAGE POWER PROCESSORS ARE FEASIBLE

- EXPLOITATION OF THE TECHNOLOGY BASE PROVIDES SIGNIFICANTLY MORE MISSION FLEXIBILITY THAN BASELINE.





## CONSIDERATIONS FOR DIRECT USE OF SOLAR ARRAY POWER

- ARRAY IS AN IDEAL RIPPLE FREE DC SOURCE, CURRENT LIMITED AND SELF PROTECTING
- THRUSTERS SCREEN POWER IS A RELATIVELY SLOW CHANGING LOAD SELF LIMITING IN CURRENT DEMAND (EXCEPT FOR ARCING)
- THRUSTER ARCING (CONTAMINATION CAUSED?) IS MORE HAZARDOUS TO PCS THAN TO ARRAYS. CONTROL TECHNIQUES EXIST FOR BOTH
- THRUSTER PRIMARY CONTROL IS MAIN VAPORIZER.



# IMPLEMENTATION CONSIDERATIONS FOR EXPLOITING THE TECHNOLOGY BASE

## I. SCREEN POWER MAY BE TAKEN DIRECTLY FROM SOLAR ARRAYS

SCREEN POWER IS  $\approx 75\%$  OF TSS TOTAL  
 $\approx 70\%$  OF WEIGHT OF PC  
 $\approx 70\%$  OF HEAT GENERATED

SCREEN PC ARE ONLY 92% EFFICIENT

ARRAY WT INCREASE IS  $8.8 \times .75 = 8.1\%$

ARRAY IS MOST EXPENSIVE SUBSYSTEM

ARRAYS WEIGH  $\approx 33$  LB/KW

PCS WEIGH  $\approx 7.7$  LB/KW

POWER SUPPLY TOTAL  $\approx 40.7$  LB/KW

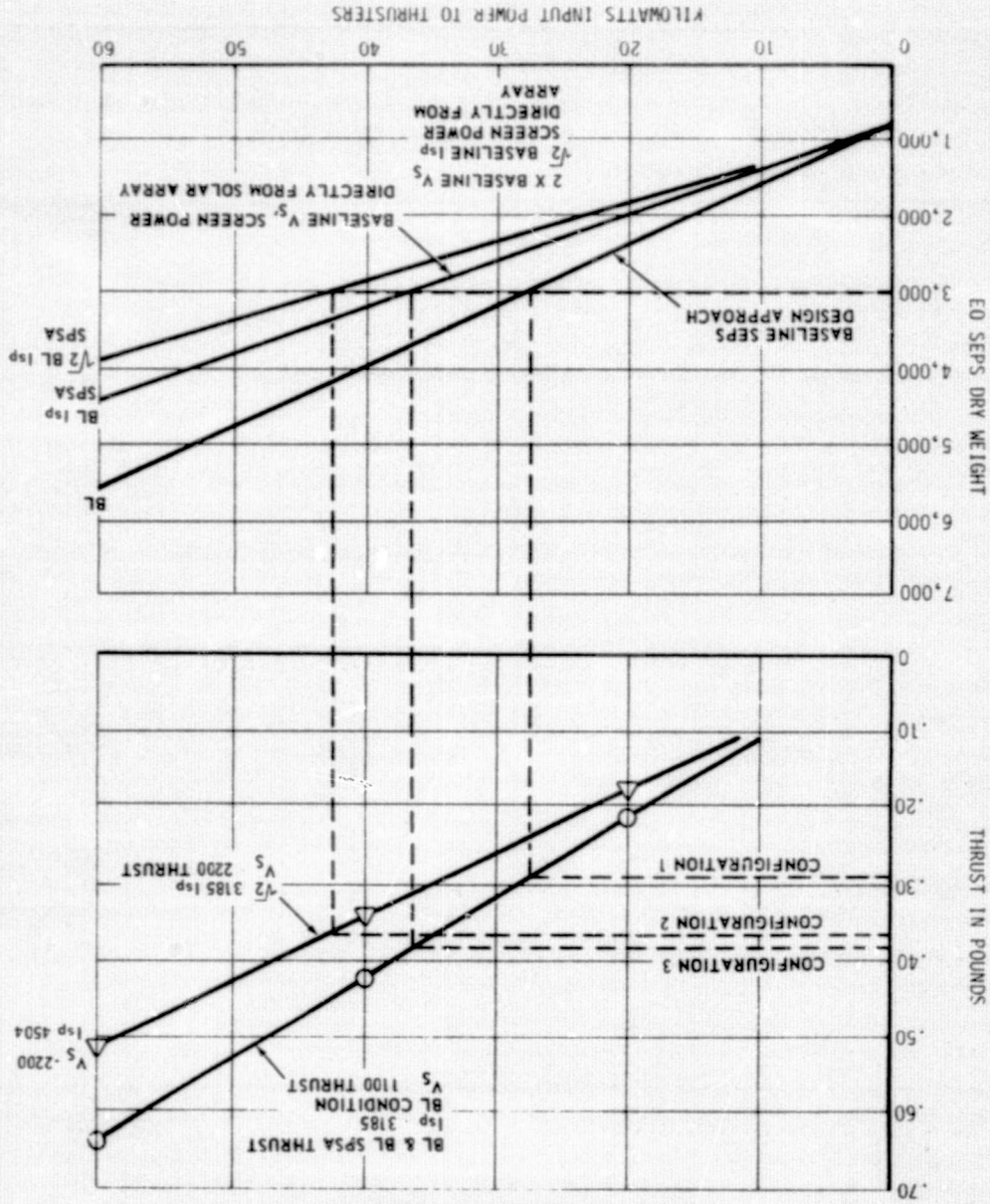
$\Delta$  WT DUE TO USE OF SCREEN PCS =  $.08 \times 33 + 7.7 \times .75$   
= 8.5 LB/KW

$\Delta$  WT SAVING POTENTIAL  $\approx 20\%$

$\Delta$  POWER GAIN FOR SAME WT  $8.5/32.2 = 26\%$



EARTH ORBITAL SEPS PARAMETRIC WEIGHT & THRUST DATA VS THRUSTER INPUT POWER  
FOR BL & ALTERNATE APPROACHES

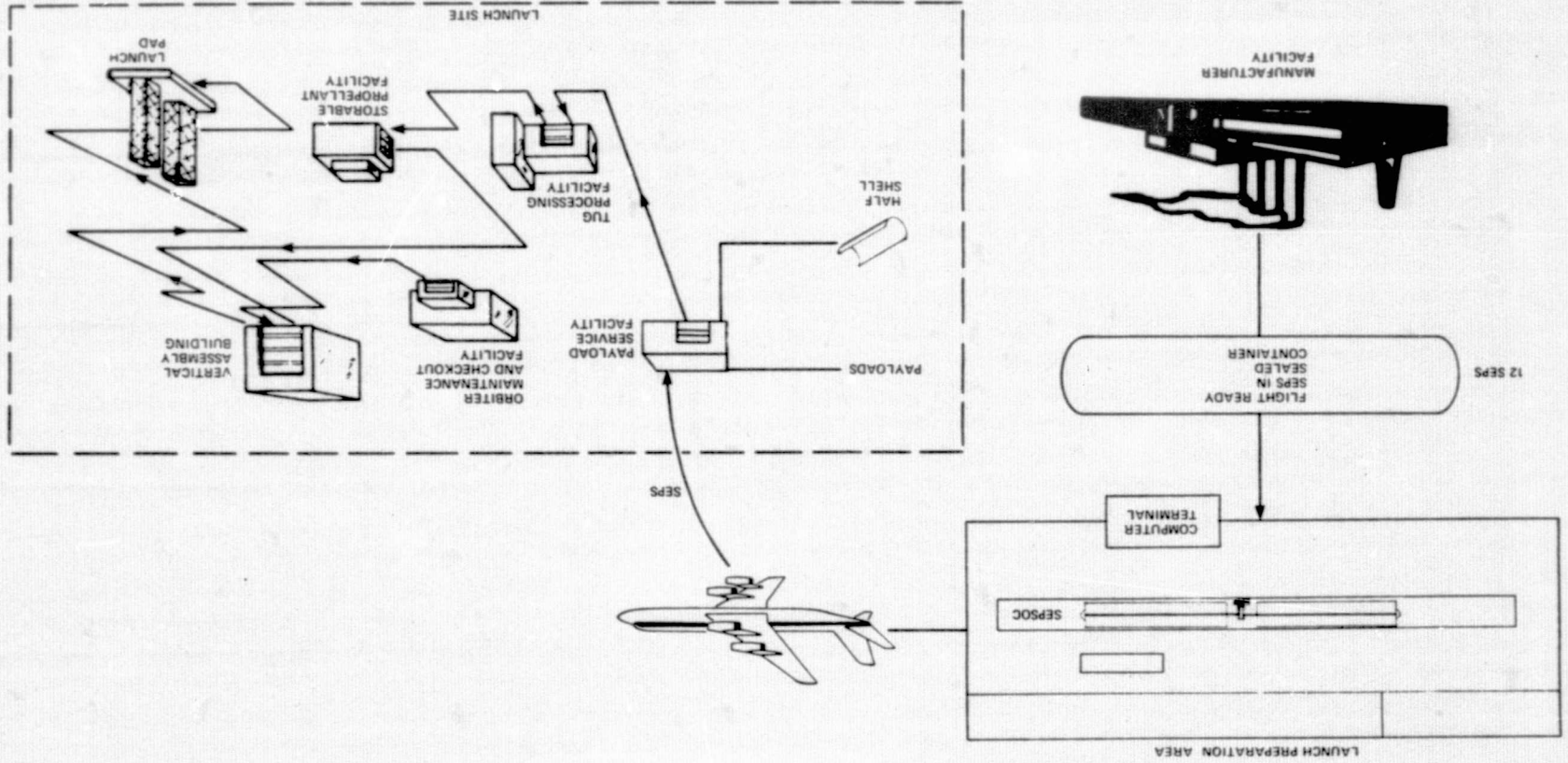


SEPS PROGRAM SUPPORT REQUIREMENTS

- o LAUNCH PREPARATION
- o FLIGHT CONTROL OPERATIONS
- o MISSION PLANNING
- o MAINTENANCE & REFURBISHMENT
- o PROGRAM SUPPORT REQUIREMENTS
- o EQUIPMENT & FACILITIES
- o SOFTWARE
- o PERSONNEL
- o COST

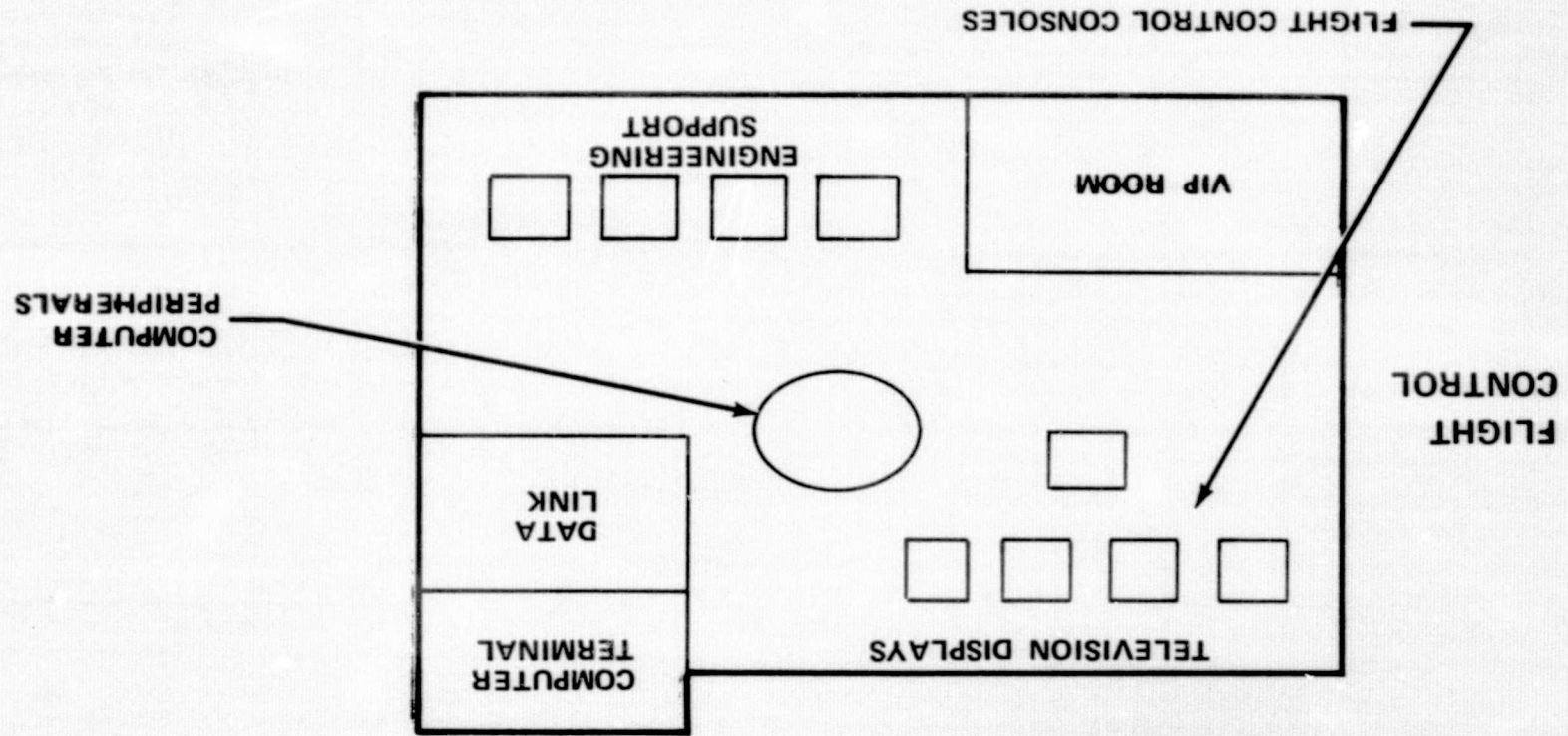


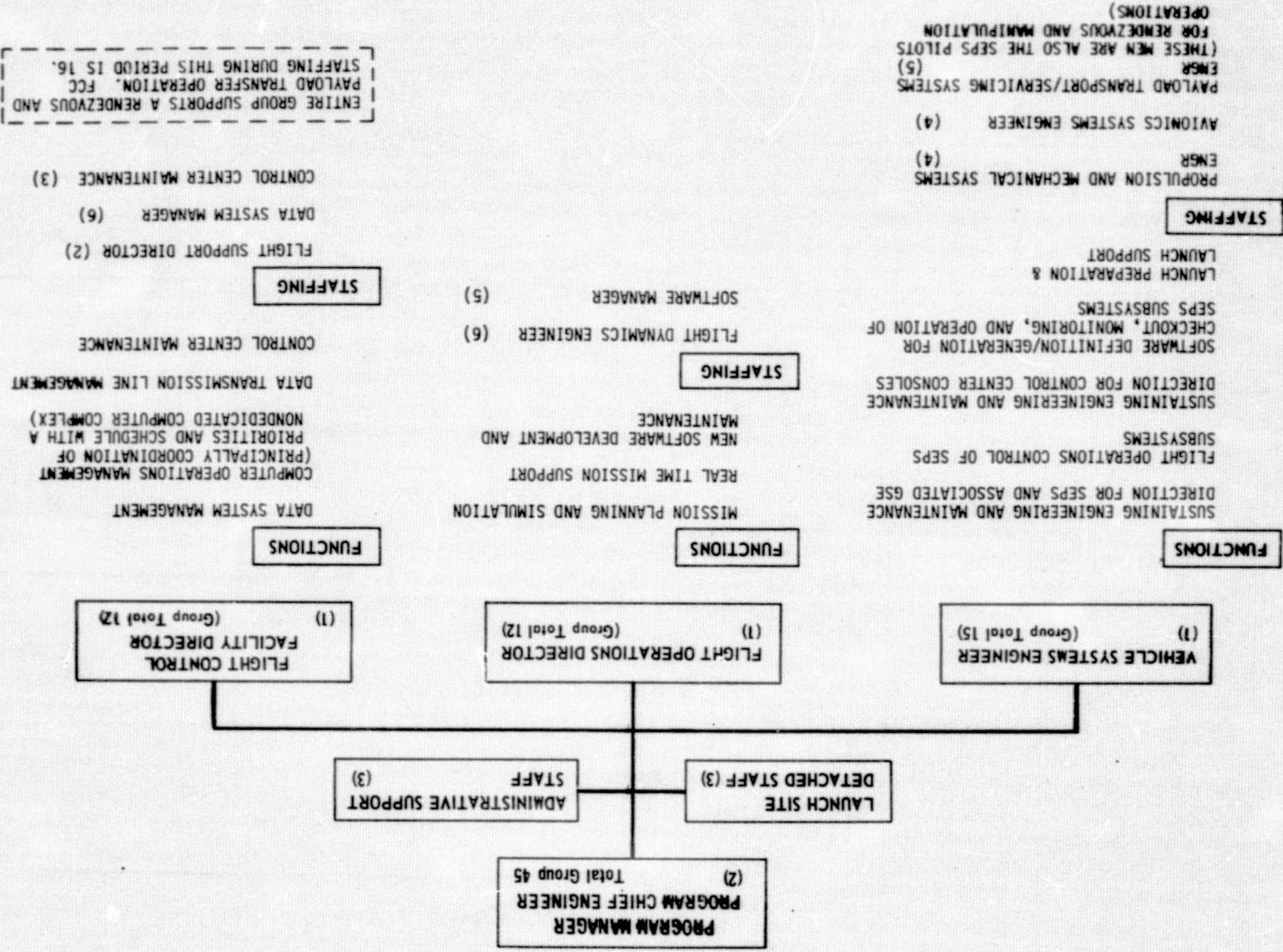
# SEPS LAUNCH PREPARATION





(SEPSOC) SEPS OPERATIONS CENTER







# OPERATIONS COST TOTAL MISSION CYCLE

START UP COST

\*EQUIPMENT

MAINTENANCE & REFURBISHMENT

SOFTWARE

FACILITIES

700,000  
23,800,000

23,700,000

PERSONNEL  
COMPUTER OPERATION

2,100,000  
25,800,000

PERSONNEL/COMPUTER OPERATION \$25,800,000 11 YEAR MISSION MODEL

÷ 29 SORTIES = \$889,655 PER SORTIE

*\*Includes 5.3 ml. for computer*



SEPS PROGRAM BASIC ASSUMPTIONS

1. COST ANALYSIS DATA IS BASED ON A SINGLE SEPS DDT&E AND PRODUCTION PROGRAM

o BASIC SEPS "CORE"

o PLANETARY KIT

o EARTH ORBITAL KIT

2. KIT CONTENT REQUIRES FURTHER DEFINITION

o KIT COST REPRESENTS 10-15% OVER BASIC SEPS "CORE"

o KIT COST = SAME

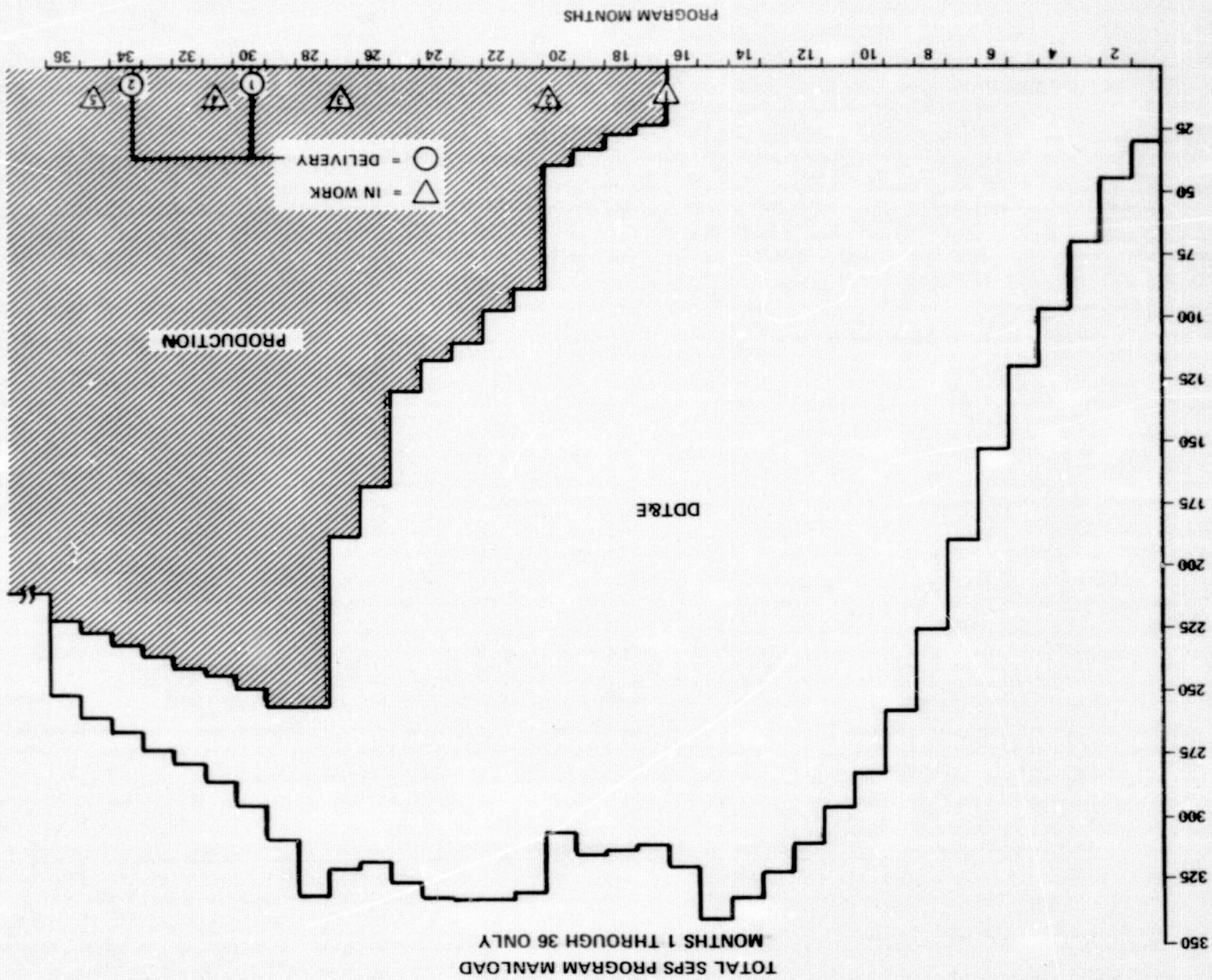
3. EARTH ORBITAL DELTA COSTS PRESENTED REPRESENT PAYLOAD TRANSPORT AND SERVICING SYSTEM

(MANIPULATOR ARM SYSTEM AND PAYLOAD MAST)

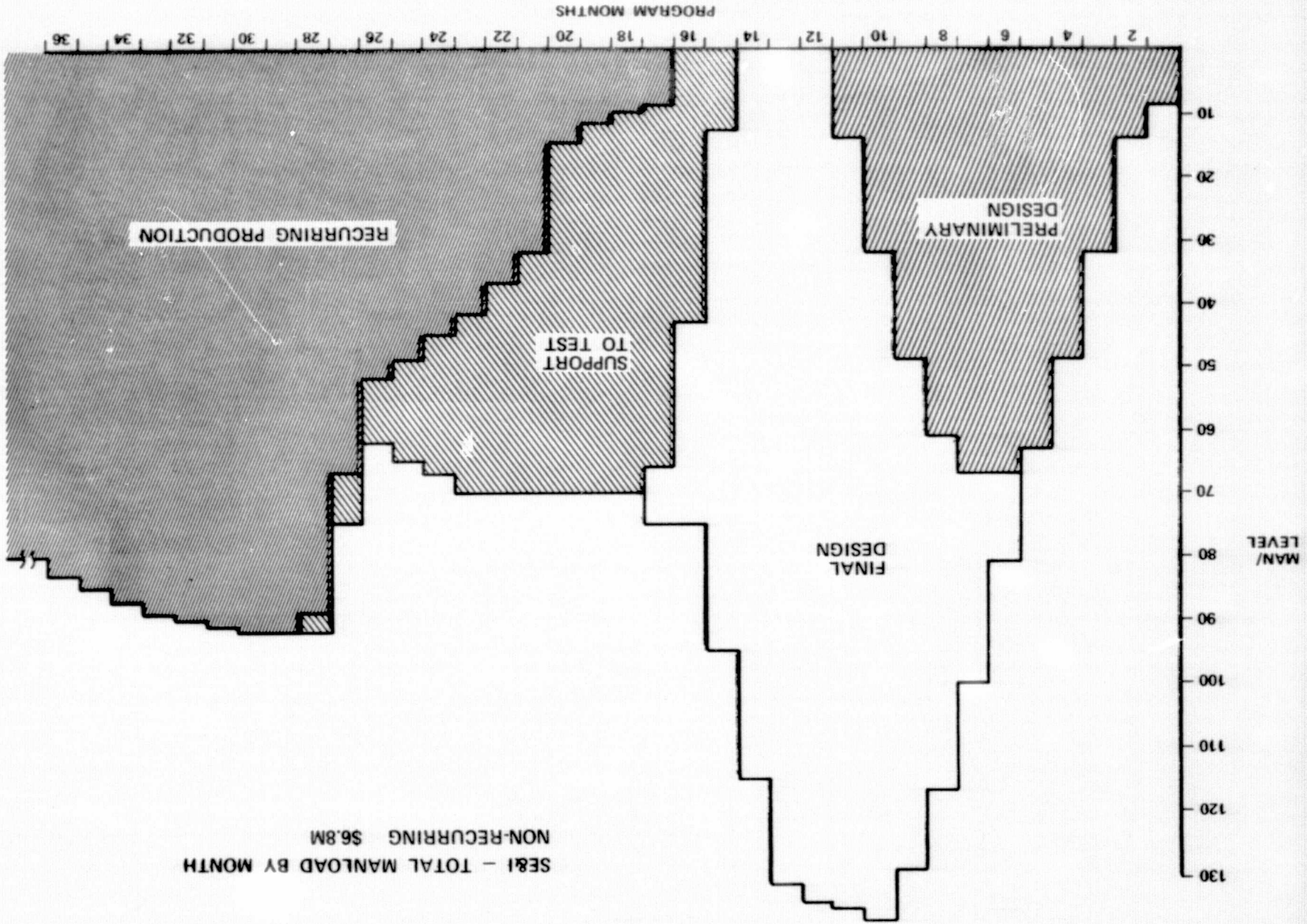
# SEPS DEVELOPMENT COSTS

STRUCTURES & THERMAL CONTROL	\$ 4.8 M
PROPULSION	9.1
POWER DISTRIBUTION	1.0
SOLAR ARRAY	7.8
DATA MANAGEMENT	3.4
COMMUNICATION	2.2
ATTITUDE CONTROL	9.2
INTEG. & TEST CHECKOUT	6.7
TEST HARDWARE	21.3
G.S.E.	10.0
SOFTWARE	4.5
LOGISTICS	2.2
S.E.&I.	6.8
PROGRAM MANAGEMENT	6.9
BASIC SEPS	\$ 95.9 M
Δ FOR EARTH ORBITAL FUNCTIONS	8.3
	<u>\$104.2 M</u>
Δ FOR TUG PAYLOAD SHELL & DIAPHRAGMS	2.5
	<u>\$106.7 M</u>

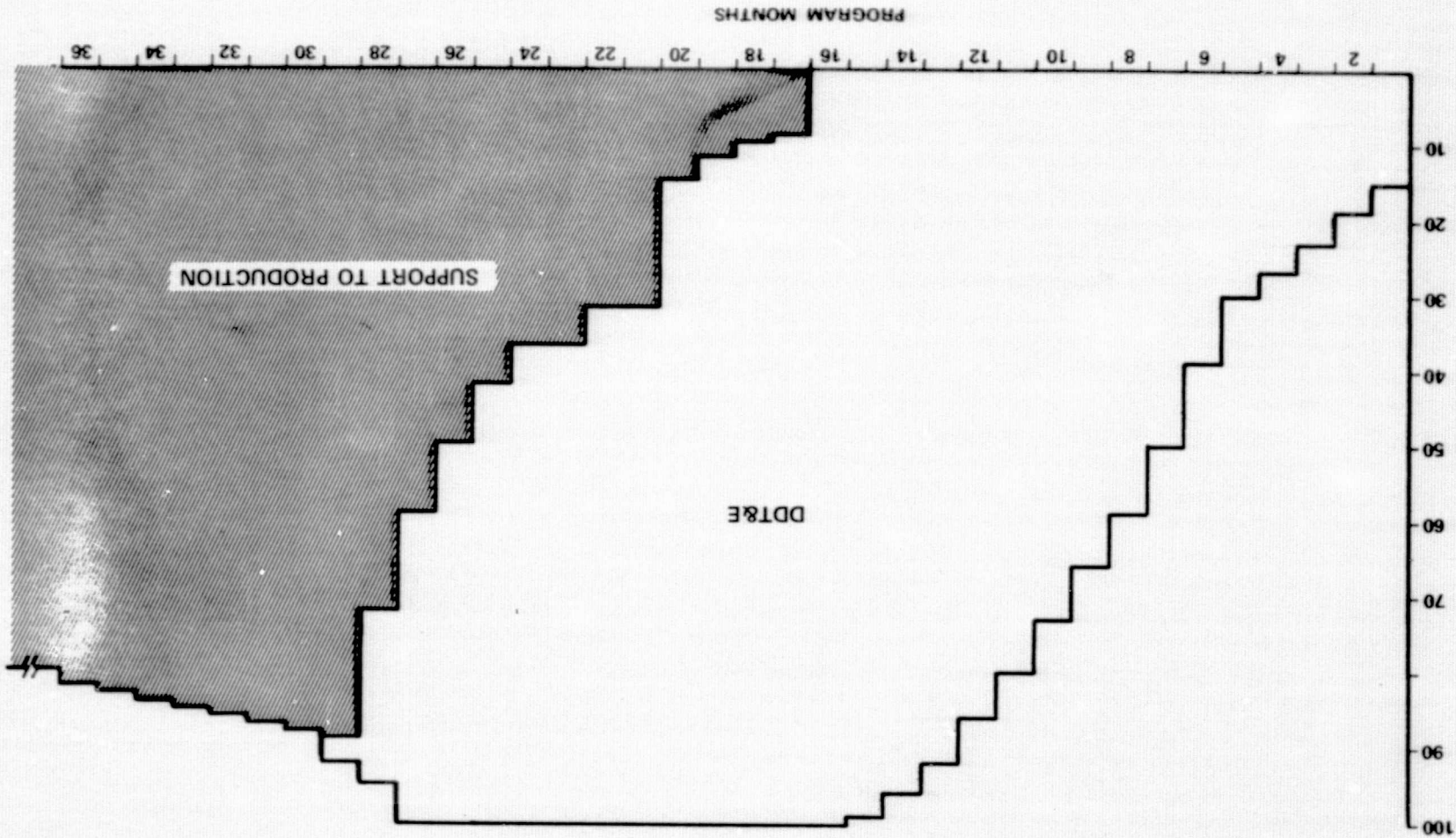








SE&I - TOTAL MANLOAD BY MONTH  
NON-RECURRING \$6.8M



PROGRAM MANAGEMENT  
DDT&E \$6.9M



RECURRING COSTS - ASSUMPTIONS AND CONDITIONS

1. COSTS ARE IN 1974 DOLLARS
2. PRODUCTION IS CONTINUOUS AND INCLUDES 11 UNITS (8 WITH PLANETARY KITS - 3 WITH EARTH ORBITAL KITS)
3. FIRST UNIT COST UTILIZED IS \$17.5M
4. AVERAGE CURVE FACTOR FOR 11 UNITS IS 69.4% OF FIRST UNIT COST. (REFERENCE N.S.I. RECOMMENDED IMPROVEMENT CURVE)



## SEPS SUMMARY COSTS

[illegible]

\*Includes \$5.3M for computer.

\*\*Additional \$4.5M included in stage DDT&E (Total \$13.2M)

SYSTEM OPERATIONAL PROFILE AND TRANSPORT  
COST EFFECTIVENESS ANALYSIS ACCOMPLISHMENTS

- DEFINITION OF OPERATIONAL MODES FOR NEAR MINIMUM STS FLIGHTS WITH  
MINIMUM SEPS TRIP TIMES DEFINED
- IMPLEMENTATION OF MODES IN A COMPUTER PROGRAM FOR MASTER SCHEDULING  
AND PAYLOAD ASSIGNMENT TO SPECIFIC FLIGHTS
- IDENTIFICATION OF MODIFIED BASELINE SEPS TRANSPORTATION SYSTEM  
SAVINGS
- IDENTIFICATION OF INCREASED POWER & Isp ADVANTAGES
- IDENTIFICATION OF RADIATION DAMAGE EFFECTS FROM "OPTIMUM" TRIP TIME  
SORTIES
- IDENTIFICATION OF MOST PROMISING SEPS CHARACTERISTICS
- SENSITIVITY OF STS FLIGHTS REQUIRED TO OPERATIONAL CONSTRAINTS

CONCLUSIONS REGARDING OPERATIONAL MODES,  
CONFIGURATION DEFINITION AND SUBSYSTEM CHARACTERISTICS

- o TRANSPORTATION ECONOMY REQUIRES ABILITY TO HANDLE 5 OR MORE PAYLOADS PER FLIGHT WITHOUT MISSION SPECIALIZED EQUIPMENT
- o SEPS OPERATIONAL PHASE CAN BE SUPPORTED BY A 45 MAN TEAM
- o ELLIPTICAL SEPS-TUG TRANSFER ORBITS OFFER APPRECIABLE TRIPTIME SAVINGS
- o SEPS TRANSPORT CAPABILITIES ARE ALMOST DIRECTLY PROPORTIONAL TO POWER. PLANETARY MISSION CAPABILITY IS ENHANCED BY INCREASED POWER
- o MANIPULATOR-MAST-TRANSPORT SHELL GPMO OFFERS THE MOST ALL AROUND ADVANTAGES
- o SCREEN POWER DIRECTLY FROM SOLAR ARRAYS OFFERS LOWER COST, INHERENT ISp SELECTIVITY TO MATCH MISSION REQUIREMENTS, LOWER WEIGHT AND INCREASED RELIABILITY
- o THE THRUSTER TECHNOLOGY BASE SUPPORTS DEVELOPMENT GOALS CORRESPONDING TO OPERATION OF 30 CM THRUSTERS UP TO 4 AMPS AND NET ACCELERATION VOLTAGES SELECTABLE THROUGH THE RANGE OF 1,000 TO OVER 2,000 WITH LIFETIMES EXCEEDING 20,000 HOURS
- o OPERATIONAL SIMPLICITY, ECONOMY AND HUMAN ERROR AVOIDANCE CAN BE ACHIEVED BY EXPLOITING PRESENT COMPUTER AND SENSOR TECHNOLOGIES
- o MANY DESIGN TASKS WARRANT FURTHER DEFINITION. NSI BELIEVES THE TECHNOLOGY BASE IS COMPLETE. SUPPORT IN CERTAIN AREAS OFFERS GREAT POTENTIAL COST SAVINGS